



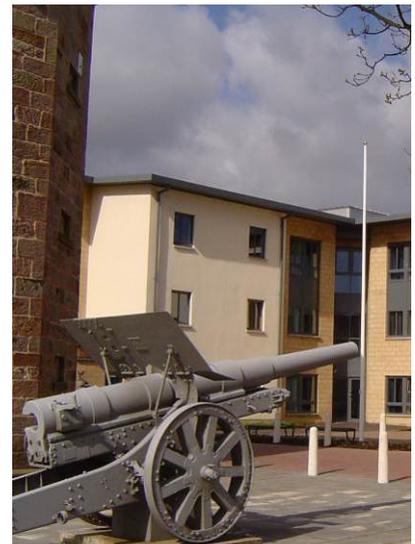
Task 318(4/45/12)

Durability of High Friction
Surfacing

Report 47070859

Prepared for:
Highways England

UNITED
KINGDOM &
IRELAND



REVISION SCHEDULE

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1 INTRODUCTION

1.1 Background

The following background to the project was given in the work package specification:

- “The agency applies substantial quantities of High friction Surfacing (HFS) at high risk locations. Most of this material is hot applied and virtually all manually applied. The service life of some of the hot applied materials can be as little as 3 years whereas that of cold applied materials can be 8 to 10 years.
- The existing BBA HAPAS test regime does not differentiate adequately between less and more durable hot applied products.
- Details of the testing currently carried out is available in the report from Project 136(4/45/12)ARPS, *Performance specified surface dressing for trunk roads – Sub-Task 3 – Desk Study of Scuffing Test Methods.*”

At start of this project, it was understood that a number of contractors have contacted the Highways England expressing concerns that their cold applied products do not fit into the existing HAPAS product assessment scheme. They consider that the existing scheme does not reflect the claimed superior durability of their products compared with hot applied HFS. Consequently, there is a need to re-evaluate the suitability of the existing testing regime to establish whether it can be used to obtain an indication of the durability of HFS materials; otherwise, a new testing regime should be developed.

1.2 Scope of Work

The main objective of the project was to identify laboratory test(s) that will indicate the likely performance and durability of HFS materials of all types. This work included review of suitability of the current test methods and made provision to identify separate tests for HFS with different binder types. These objectives were delivered under the following stages of work:

1. Literature Review, including meeting with industry associations.
2. Laboratory testing of the existing and new test methods, including assessing the test precision.
3. Developing test method.

The above approach is summarised in Figure 1.

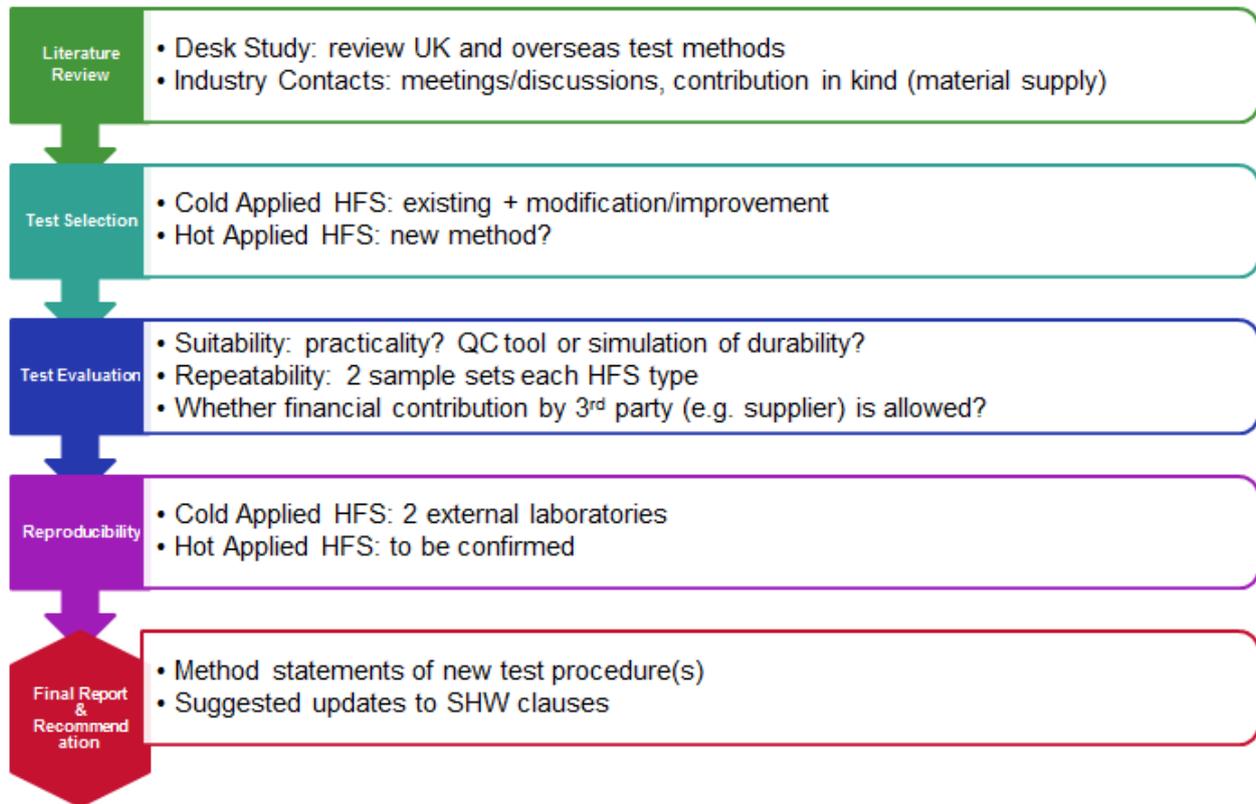


Figure 1: Summary of approach to the study

2 LITERATURE REVIEW

A desk study was carried out on published data related to testing of HFS materials, both in the UK and overseas. During this review, known testing regimes and how they have been related to in situ performance are summarised. These included discussions and meetings with HFS material suppliers and users, and BBA HAPAS approved testing laboratories. All proprietary HFS materials, both cold and hot applied, are considered in this review.

To start with, this review took on board recommendations presented in previous work (Task 136), reported by URS (now AECOM) for the Highways England. These recommendations are summarised here:

- For cold applied (thermosetting) HFS systems, the current Scuffing Test protocol should be revised and updated as a single document containing a full test method. This new document should consider the range of factors which may affect the repeatability and reproducibility of the test method.
- For hot applied (thermoplastic) HFS systems, an alternative test method should be considered to account for the characteristics of thermoplastic systems. The alternative test method should be discriminatory, repeatable and reproducible; it should also be performed on the melted material taken from the boiler on site, be of sufficient mass to negate variations within the mixture, should investigate the thermo-mechanical properties of the mixture and, ideally, be able to be performed by manufacturers to aid in development and quality control. This future work should involve distinctively defining erosion or “wear” under the scuffing test and validating the test results against the performance of thermoplastic systems in situ.

2.1 Review of alternative test methods

It was agreed during the project meeting that there is no immediate need to replace the existing scuffing test method for cold applied broadcasted HFS as the current test method only requires a slight adjustment in order to improve clarity of the protocol and precision of the test results. On the other hand, screeded HFS, particularly those with thermoplastic binders requires completely different test method due to the reasons presented in the above summary (Task 136). Consequently a search was carried out on alternative test methods which may be applicable for the assessment of screeded HFS systems.

Table 1 presents a summary list of alternative test methods, showing those which have been used for assessing asphalt materials and those which can be modified to assess screeded HFS systems. More details of these methods are presented in Table 2.

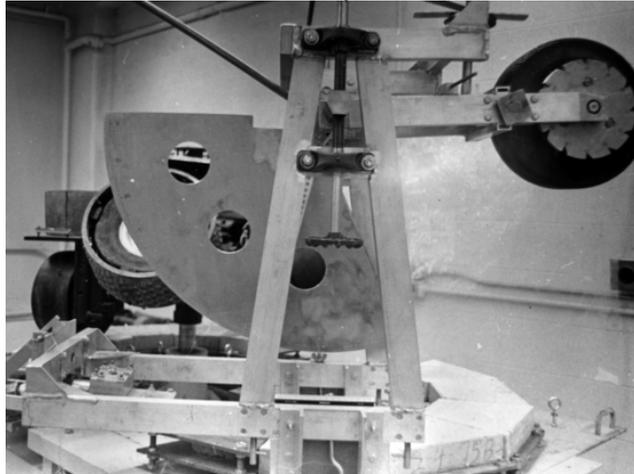
Table 1: Summary of test methods under review

Name of Test	Standard (reference)	What it measures	Durability or Simulative Test?	Practical application
Scuffing test at cyclic temperature	Modified Appendix G, TRL176	Erosion	Durability	Lab. Require substantial modifications to existing equipment.
Scuffing with studded tyre	Modified Appendix G, TRL176	Erosion	Durability	Lab. Require substantial modifications to existing equipment. Not feasible.
Scuffing under water (Hamburg wheel track)	En 12697-22	Erosion	Durability	Lab. A possibility but substantial equipment modification and test protocol is required.
Wheel track with studded tyre	ASTM E660	Wear test	Durability	Lab. Equipment not available in UK.
Road Machine	TRL 176, Appendix H	Wear test	simulative	Lab. Expensive if used for routine assessment
Dutch Rotating Surface Abrasion Test (RSAT)	prCEN/TS 12697-50:2014	Wear test	Simulative	Lab. Equipment not available in UK.
ARTe (the Aachener Raveling Tester)	prCEN/TS 12697-50:2014	Wear test	Simulative	Lab. Equipment not available in UK.
Prall tester	prEN 12697-16 DFP	Abrasion by studded tyres	simulative	Lab. No track record on very thin surfacing.
Wehner Schulze	TRL report 144	Polish value of aggregates	simulative	Lab. Not reliable track record.
Shear Bond Strength	DE Spec 45; prEN 12697-48	Shear strength	Durability	Site, Lab. A possibility for adaption.
Tensile Adhesion	TRL 176, Appendix J	Tensile strength	Durability of binder	Site, Lab. A possibility for adoption.
Indirect Tensile (Splitting)	BS EN 12697-23	Tensile Strength	Durability of binder	Lab. A possibility for adoption.

Table 2: Descriptions of test methods under review

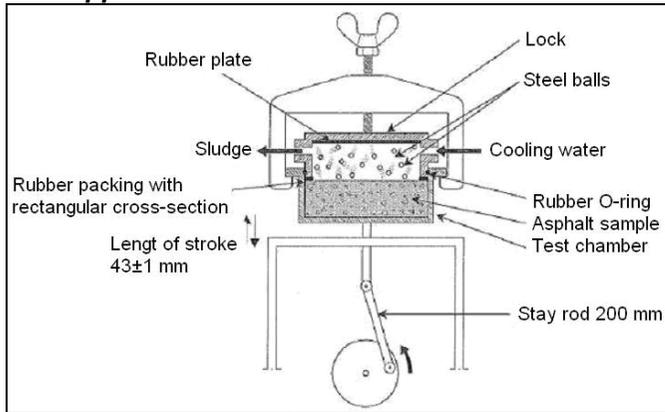
Test	Descriptions/Comments
<p data-bbox="138 368 483 400">Scuffing- wheel apparatus</p> 	<p data-bbox="884 400 2101 646">Scuffing-wheel apparatus consists of a loaded wheel which bears on a specimen held in a moving table. The table moves to and fro beneath the wheel with the axle of the wheel held at an angle of $(20\pm 1)^\circ$ to the vertical plane perpendicular to the direction of travel. The test is described in TRL report 176 and is being currently used for the erosion measurements on the High Friction Surfacing. The test is simulative which will consider the traffic action however; there was a perceived issue with accumulation of heat due to friction between tyre and the surface and this has led to embedment of chippings into thermoplastic HFS and made the interpretation more problematic. There is however scope to improve the test method, to allow its application for non-thermoplastic HFS.</p>
<p data-bbox="138 837 427 869">Hamburg wheel-track</p> 	<p data-bbox="884 837 2101 1114">This device measures the combined effects of rutting and moisture damage by rolling a steel wheel across the surface of an asphalt concrete specimen that is immersed in hot water. Each steel wheel passes 20,000 times or until 20 mm of deformation is reached. The measurements are customarily reported versus wheel passes. This is a simulative test method with similar limitation as scuffing test, that there could be issue with testing thermoplastic HFS as aggregates may become embedded into the material and this may make interpretation become problematic if tests were carried out at elevated temperatures. However if the wheel can be set to an angle similar to that of TRL 176 scuffing test, there is a potential to explore the usefulness of this test if carried out at lower temperatures and in water. This is subject to further research.</p>

Wheel track with studded tyre



ASTM E660 test method describes a laboratory procedure for estimating the extent to which aggregates or pavement surfaces are likely to polish when subjected to traffic. Specimens to be evaluated for polishing resistance are placed in a circular track and subjected to the wearing action of four small-diameter wheels with or without use of abrasive. Terminal polish is achieved after approximately 8 h of exposure. Pneumatic tyres are used for assessing wear of asphaltic materials whilst steel wheel with studs mounted in the periphery is normally applied for assessing concrete surface. However similar to the limitation of scuffing test, there could be issue with testing thermoplastic HFS as aggregates may become embedded into the material and this may make interpretation become problematic if tests were carried out at elevated temperatures. Furthermore the equipment is not available in the UK.

Prall apparatus



The Prall method is described by EN 12697-16:2004. It was developed to determine wear resistance of asphalt mixtures. The pavement sample with height 30 mm and diameter 100 mm is conditioned in water at 4-5°C, before it is put in a test chamber with 40 steel balls. The steel balls, which are 12 mm in diameter, hammer the sample driven by a stay rod which rotates with 950 RPM, and cooling water is flushed through the chamber with efficiency 2 litre per minute. Particles torn loose from the sample are washed out by the cooling water into a collector and finally the Prall value is calculated. Requirements for resistance to studded tire wear after Prall method, wearing course (Norwegian public road administration, Handbook N200). Nevertheless, Prall test is not a simulative test and the test adaptation in the UK may not be realistic since the use of studded tyres is limited.

Dutch Rotating Surface Abrasion Test (RSAT)



The RSAT method was developed to reproduce the scuffing damage as it occurs on real life pavement roads. This test method is current being considered by Technical committee CEN/TC227/WG1 for inclusion in prCEN/TS 12697-50:2014. The motion of the wheel in relation to the test specimen shall be as shown in this figure. The motion of the arm shall be constant, with the guiding arms playing a part in ensuring constancy. The rotation of the test specimen shall be caused by the turning forces of the tyre-road action. In order to stimulate the shear stresses, the slab shall be blocked in one direction by a brake. Either slabs or cores can be tested. The slab shall be an octagon shape. The length and width shall be approximately 500 mm x 500 mm. The thickness can vary between 30 mm and 60 mm. Cores shall have a diameter of (150 ± 1) mm and a height between 30 mm and 60 mm. Three cores can be tested in one test. The cores shall be fixed in an octagon shaped mould. During the test, all loose material shall be removed from the surface of the specimen using a vacuum cleaner. By separating mineral aggregates from the rubber, the aggregate loss during the test shall be determined. The test is simulative and considers the traffic action however; there could be issue with accumulation of heat due to friction between tyre and the surface and this may complicate interpreting results on thermoplastic HFS.

The ARTe (the Aachener Raveling Tester) apparatus



The ARTe is one of the four types of equipment described in the present version of a new technical specification which is being developed by Technical committee CEN/TC227/WG1. The test is performed in a temperature controlled room which is ventilated and capable of allowing the temperature of the slab fixation box and the average temperature of the air draught at tens of centimetres from the slab to be fixed at a temperature of (20 ± 2) °C throughout the duration of the test. During the test, the lateral moving table travels 600 times forwards and backwards over the slab. During that time, the wheels are rotating with (47 ± 1) rpm. After half the number of load repetitions, the slab fixation box will be rotated 180°. After finishing the test, the slab will be removed from the slab fixation box. Loose material shall be removed from the surface of the slab using a vacuum cleaner. The surface shall be inspected visually and any differences between the initial and end surface will be reported. The ARTe test gives repeatable results and most of the tested mixtures behave as expected. The confidence in the test results is good, because it is a realistic, yet relatively simple test. A study conducted by Belgian Road Research Centre concluded that the ARTe-test is the most suitable laboratory test to simulate the effect of shear forces induced by traffic. However, it needs to be modified to consider the pore pressure effect and moisture damage mechanism. As RSAT, there could be issue with accumulation of heat due to friction between tyre and the surface which may complicate interpreting results on thermoplastic HFS.

Shear Bond Strength



This test method is currently specified for slurry surfacing produced to Defence Infrastructure Organisation (DIO) Specification 045, to assess early life and long-term performance of the material. Materials meeting Table 4.2 of the specification criteria will be deemed as acceptable under the contract.

Furthermore, DIO has commissioned another study to extend application of this test method to measure surface shear strength of asphalt surfacing. Considering the simplicity and practical aspects of this method, and the track record on its use on slurry surfacing, this method is considered as a viable option for assessing stability of HFS materials.

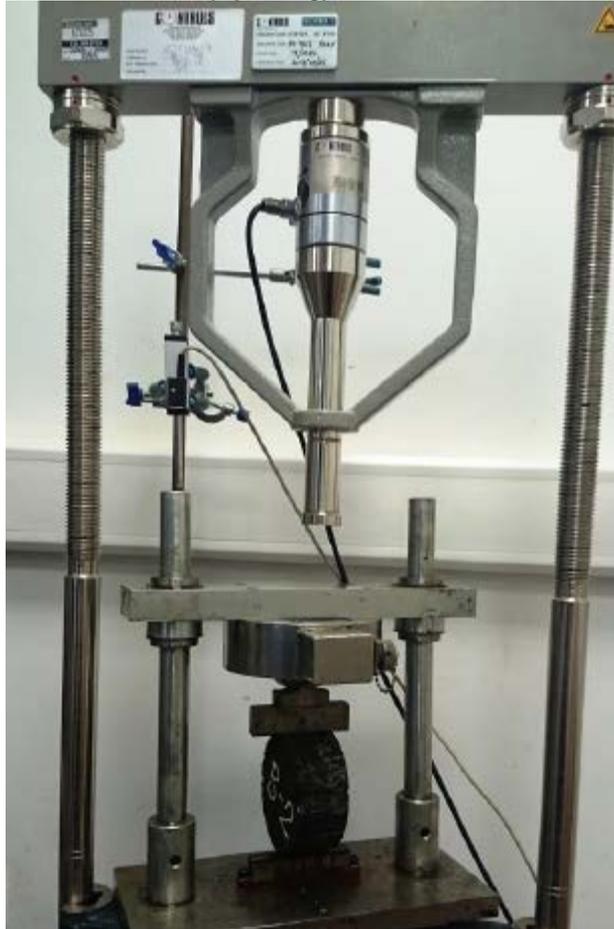
Tensile Adhesion



This test method has been considered by a number of HFS suppliers as part of quality control of newly installed products. Examples of values of obtained for an HFS applied over different surfacing is summarised below. This is a crude method to determine early strength of the material, contributed by the performance of the binder in the mix. Therefore there is a potential use of this method albeit low precision.

Substrate	Tensile Strength
Asphalt	0.5 MPa (failed at substrate)
Concrete	3 MPa (failed at substrate)

Indirect Tensile (Splitting)



This is a very simple but standardised test which has been widely adopted for concrete and asphalt materials testing. The test involves applying monotonic vertical loading to a cylindrical specimen until the specimen fails into halves (i.e. split) and the maximum force and the associated deformation are recorded. The test does not directly represent resistance of material against lateral force, however it has been known to provide good indication of the binder cohesion in bituminous mixtures which often affected by excessive heating during production. Considering the current practices during laying and production of thermoplastic HFS, where block of cold HFS materials are often re-heated under gas burner prior to laying on site, this test could help in managing the QA/QC (quality assurance/quality control) process during construction.

Considerations were taken based upon the benefits and limitations offered by each test method, as well as the availability of, or access to, the equipment for adoption during mix design and quality assessment during resurfacing works in England. This has narrowed down the option into the following test methods:

- 1) Modifying the current scuffing test method, to improve precision, for testing cold applied broadcast HFS;
- 2) Developing a new test method for testing hot and cold applied screeded HFS, based on the principle of shear bond test;
- 3) Considering indirect tensile test method for assessing as-supplied quality of hot applied screeded HFS.

2.2 Liaisons with industry

Contacts were made with representations from two major associations dealing with surface treatments, specifically Road Surface Treatments Association (RSTA) and Road Safety Markings Association (RSMA). The aims of these contacts were:

- Gathering practical experience on application of their products, from the mix design, specification requirements and performance in situ.
- Providing opportunity to RSMA and RSTA members to participate directly in this project by means of providing HFS materials and the associated information.
- Establishing a communication line between the research team (AECOM) and the participating industry suppliers.

A number of face-to-face meetings have been held as described in Table 3. In summary, the study received positive responses from the industry and many members were keen on participating in this project, a number of suggestions for improving the current test methods were also noted for consideration during this study. Those who had expressed interest to participate are listed in Table 4. However, considering the limitation on time and budget to deliver this study, only a few of them were selected. The process of selecting which products for inclusion in this study has been communicated to RSTA and RSMA by email dated 22 May 2014; a copy of this email is reproduced in Appendix A. For clarity the selection process is reproduced below:

Within the scope of this study, we have allocated 4 sets of HFS materials to be trialed and assessed using the new or modified method(s) at no cost to the material suppliers, under the following conditions:

- If there are more than 4 materials being proposed by the suppliers, we will shortlist them and select 4 representative sets.
- The identity of the samples selected for testing will only be known by the URS register and the respective suppliers, otherwise unique numbers will be allocated for these samples and they will be made anonymous in our reports and discussions.
- If other suppliers whose materials are not selected for testing would like to be included in this study, they would be requested to cover the cost for testing and need to meet a deadline for supply of material.

At the end of this study, both RSTA and RSMA will receive an electronic copy of the final report presenting the findings from this study.

For the cold applied broadcast HFS, where precision of the test method and improvement to the protocol would be developed, two independent laboratories agreed to participate in this study:

- PTS International in Kent – contact name: Tony Sewell.
- Thameside Test & Research Ltd in Kent – contact name: Paul Shrubsole.

For the screeded HFS, all tests were carried out at AECOM's specialist laboratories in Nottingham.

Table 3: Timeline of liaison with industry

Date	Industry Contact	Summary of the meeting
14 July 2014	RSTA – Mike Harper	Meeting was held at AECOM Nottingham, attended by Mike Harper (RSTA). During this meeting, Daru Widyatmoko (AECOM) and Martin Heslop (Acland) presented an overview of the research and opened discussion for RSTA involvement in this study. It was responded positively by Mike who offered support for information and materials for this study.
17 July 2014	RSMA – George Lee	Meeting was held at AECOM Nottingham, attended by George Lee and John Lloyd (RSMA), Martin Heslop (Acland) and Daru Widyatmoko (AECOM). During this meeting, Daru presented an overview of the research and opened discussion for RSMA involvement in this study. It was responded positively by George who offered support for information and materials for this study.
30 July 2014	Stirling Lloyd – Frank Swallow	Meeting was held at Stirling Lloyd R&D office in Cheshire. Discussions were held on scuffing test following discrepancies between data generated at different test houses. Following the discussion, the following recommendations were considered: 1. To tighten up on the protocols of the scuffing test for cold applied epoxy and methacrylate. 2. To offer an alternative method for assessing the suitability of hot applied thermoplastics. One outcome of this study might be the differentiation of Type 1 materials by reference to the types of application areas on which each may be recommended, rather than the introduction of a separate (higher) classification, though the concept of a Type "0" is not precluded at this stage.
12 November 2014	RSMA – Annual Conference	The annual conference was held in Derbyshire. Donald Burton (HE) presented best practices and design guide on HFS system, including an introduction of this study.
6 January 2015	LKAB Minerals – Mark Moriarty	Meeting was held at LKAB Minerals R&D office in Derby, attended by Mark Moriarty (LKAB Minerals) and Daru Widyatmoko (AECOM). Discussion was held on production and supply of high PSV aggregates and their characteristics in relation to adherence with HFS binder.
19 February 2015	LKAB Minerals – Mark Moriarty	Meeting was held at AECOM office in Bedford, attended by Mark Moriarty (LKAB Minerals), Donald Burton (HE), Martin Heslop (Acland) and Daru Widyatmoko (AECOM). This was a follow up meeting to discuss further about different sources, process and options for high PSV aggregates and their anticipated durability such as alumina content).

Table 4: Expression of support from RSTA and RSMA members

Company Name	Contact Person	Product Name	Product Type	BBA HAPAS Certificate no.	Type	Binder
Adbruf Ltd	Steve McGilchrist; Sales & Marketing Director	HotGrip	Polymer modified Hot melt adhesive	05/H111	2	Thermoplastic
		ColdGrip	Cold applied polyurethane binder	02/H066	1	Polyurethane
Ennis-Flint EMEA	Shaun Friel; Product Development Manager	Prismo Zebraflex	Hot polymer modified plasticised rosin ester	00/H043	1	Thermoplastic
		Suregrip	Cold Applied	98/H002	1	Epoxy
		Tyregrip	Cold Applied	05/H115	2	Epoxy
Hitex	Alan Taylor	Hitex Textureprint	Hot-applied	04/H088	1	Thermoplastic
	John Lloyd	Ecogrip Epoxy	Cold-applied	14/H212	1	Epoxy
joblingpurser	Richard Vallance; Area Sales Manager	Rocbinda/Colorvial	Cold-applied	12/H196	1	Polyurethane
Lkabminerals	Mark Moriarty	bauxite based product	-	-		
		Olivine based product	-	-		
Stirling Lloyd	-	Safetrack® HW	Cold applied	04/H090	1	MMA
Star Uretech	Robert Jackson	Uretech HFS	Cold applied	11/H177	1	Polyurea
Colas	John Richardson	SprayGrip	Cold applied	98/H001		Epoxy

2.3 Adopted scope of laboratory assessments

Considering the findings from literature review and feedback from the industry, the scope of laboratory assessment were agreed with the project sponsor. Details are presented in the following chapters and an overview is summarised in Table 5.

Table 5: Scope of laboratory assessments

Description	HFS type/application	
	Broadcast system	Screeded system
Number of sample sets	2	2
Number of laboratories	2	2
Modified TRL 176/BBA HAPAS test protocol	Yes	Yes
Modified shear bond strength test protocol	Yes	Yes
Indirect tensile strength test	No	Yes

3 HOT AND COLD APPLIED SCREEDED HFS

A total of 3 test regimes were developed for hot applied screeded HFS; detail test protocols are presented in Appendix B and discussions are presented below. The 3 test regimes comprise of, Shear Surface Strength (SSS), Shear Bond Strength (SBS) and Indirect Tensile Strength (ITS) testing. A cold applied screeded HFS was also tested.

3.1 Sourcing of Materials

Material was supplied by suppliers of hot applied HFS having HAPAS certificates. Material was applied to asphalt surfacing by TTR using the screeding method as carried out on site in accordance with BBA/HAPAS guidelines.

3.2 Development of SSS, SBS and ITS testing for Hot and cold applied screeded HFS.

It was understood that main points of failure within a screeded HFS included:

- Cracking due to internal failure or substrate cracks reflecting through the HFS.
- Delamination due to water ingress (through cracks or edges) or poor adhesion/bond.

As a result a test was identified to determine the internal shear strength of the HFS and a further test identified to determine the bond strength between the substrate and HFS. Both tests required adaptability between both laboratory and site testing.

3.2.1 SSS development

The Shear Surface Strength test was developed to investigate the internal shear strength properties of an HFS material. This test can also be used for assessing the asphalt substrate. Figure 2 illustrates how the SSS test can be performed.

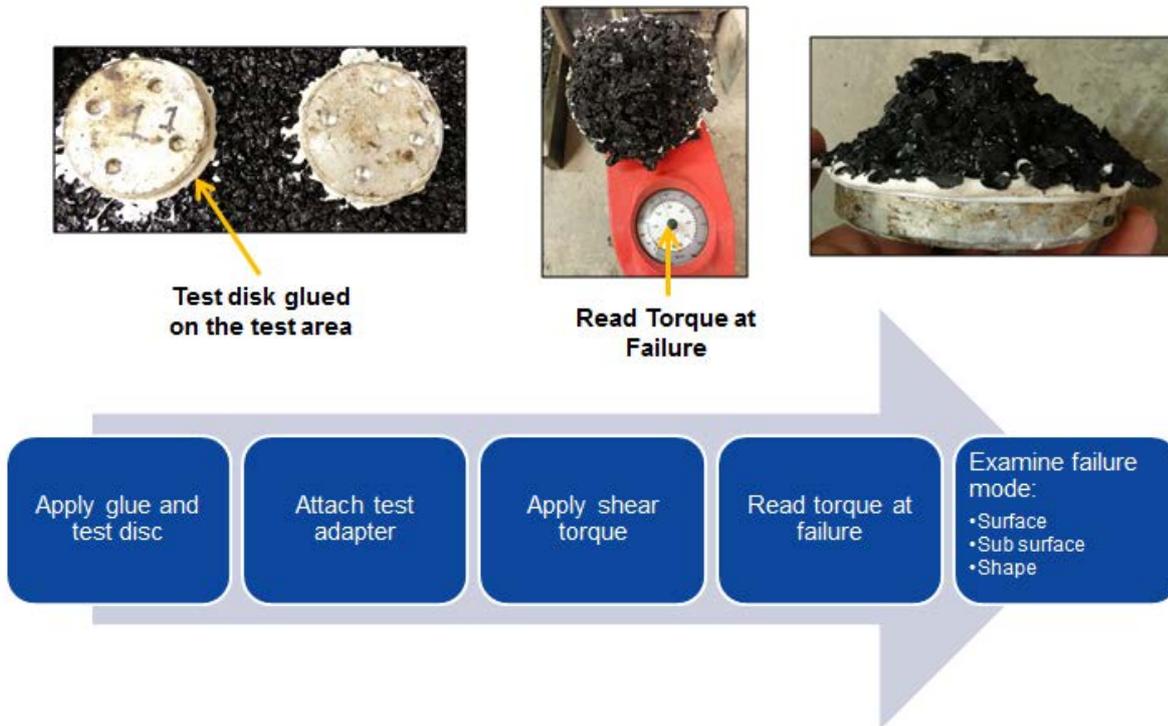


Figure 2: Snapshot of SSS Test Protocol

Initial trials were carried out in partnership with Thameside Test and Research Laboratory (TTR), asphalt slabs were screeded with hot applied HFS and 100mm diameter metal discs were adhered to the surface of HFS surface.

The metal discs were glued to the surface, a trial was also conducted whereby a metal disc was heated up to a temperature close to that of the HFS material and applied, with pressure, to the HFS immediately after application.

An 800Nm torque wrench was connected to the metal disc via an adaptor. The torque wrench was set to zero and loaded, the peak torque at failure was noted and converted from Nm to kPa to provide shear strength using Equation 1.

Equation 1:
$$\tau_{SSS} = \frac{12 \times M \times 10^6}{\pi \times D^3}$$

Where:

M= Peak load (Nm)

D= Diameter of metal disc (mm)

τ_{SSS} = Surface Shear Strength (kPa)

Test results

A number of attempts have been made to carry out SSS on newly applied HFS on both new and old asphalt substrates. These tests were attempted both HFS over thin surfacing and HFS over HRA substrates. However, all tests resulted in no failure within the HFS layer; the recorded SSS values were found in excess of 2000

kPa with failure taken place at the interface between the test disc and the HFS. Figure 3 illustrates these tests.



Figure 3: SSS test setup for asphalt substrate (left) or HFS over asphalt substrate (right)

As stated previously, the test can also be conducted on the asphalt substrate. A number of asphalt slabs were manufactured in laboratory and they were subjected to SSS tests. Some samples were subjected to an accelerated ageing (in accordance with Appendix A.12 of the BBA HAPAS Document SG3/08/256) prior to the SSS tests. The results are presented in Table 6.

Table 6: SSS test on laboratory manufactured thin surface course

Details		@ 20°C		@ 35°C	
Binder	Condition Regime	Torque (Nm)	τ_{SSS} (kPa)	Torque (Nm)	τ_{SSS} (kPa)
Standard 40/60 Pen	Unaged	440	1681	350	1337
		350	1337	300	1146
		300	1146	310	1184
	After Ageing	720	2750	410	1566
		780	2979	410	1566
		780	2979	450	1719

The results suggest the influence of test temperature to the SSS values. The results also suggest that newly manufactured and sound thin asphalt surfacing would have SSS value not less than 1100 kPa when tested at temperature up to 35°C.

3.2.2 SBS development

Shear Bond Strength testing allows the bond between the Asphalt Substrate and the HFS to be tested. It was developed as an adaptation of the SSS test detailed above, the first tests were conducted by isolating, via the use of isolating metal/collar, as seen in Figure 4. Also, the SBS (τ_{SBS}) is calculated in the same way as τ_{SSS} shown in Equation 1.



Figure 4: Photograph taken of HFS application in isolating metal mould

Sketch of the isolating metal/collar can be seen in Figure 5. This required the material to be poured into a collar (heated for hot applied to HFS temperature) followed by the test disc, followed by pressure.

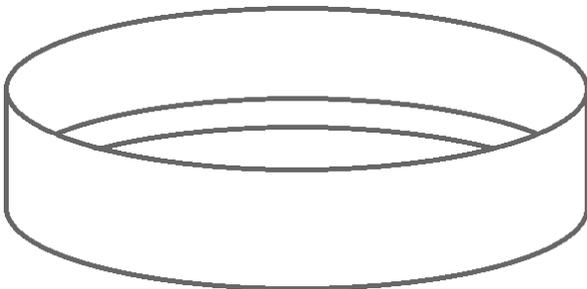


Figure 5: Metal HFS collar sketch

This method allows the test sample to be left undisturbed as it cools/cures, after which testing may be carried out, and the interface that failed should be noted and if it is between the asphalt and the HFS then temperature should be recorded.



Figure 6: Test setup for HFS over either Thin Surfacing (left) or HRA (right) substrate

Trials of newly applied thermoplastic HFS to an asphalt substrate were carried out both in situ and in laboratory:

- Samples for the laboratory assessments comprised HFS overlaying a laboratory manufactured SMA slab;
- Samples for the in situ assessments comprised HFS overlaying an existing (in service aged) thin surfacing.

In these trials, the test discs were required to be preheated up to 180°C in order to reach the temperature within 5°C of that of the HFS (around 160°C) during the application of the test disc. The results are summarised in **Table 7**.

Table 7: SBS test on newly laid HFS over thin surface course

Test Location	Sample number	HFS temperatures during test (°C)	Peak value of torque (NM)	τ_{SBS} Shear Bond Strength (kPa)	Visual Observation
Laboratory	1	21.1	≥ 600	≥ 2000	Fail at disk/HFS interface
Laboratory	2	21.1	≥ 600	≥ 2000	No failure (intact)
Laboratory	3	21.1	480	1600	Fail at disk/HFS interface
Laboratory	4	22.3	480	1600	Fail at asphalt and HFS interface
Site	1	17.2	560	1900	Fail at asphalt and HFS interface
Site	2	16.5	650	2200	Fail at disk/HFS interface
Site	3	17.0	≥ 600	≥ 2000	No failure (intact)

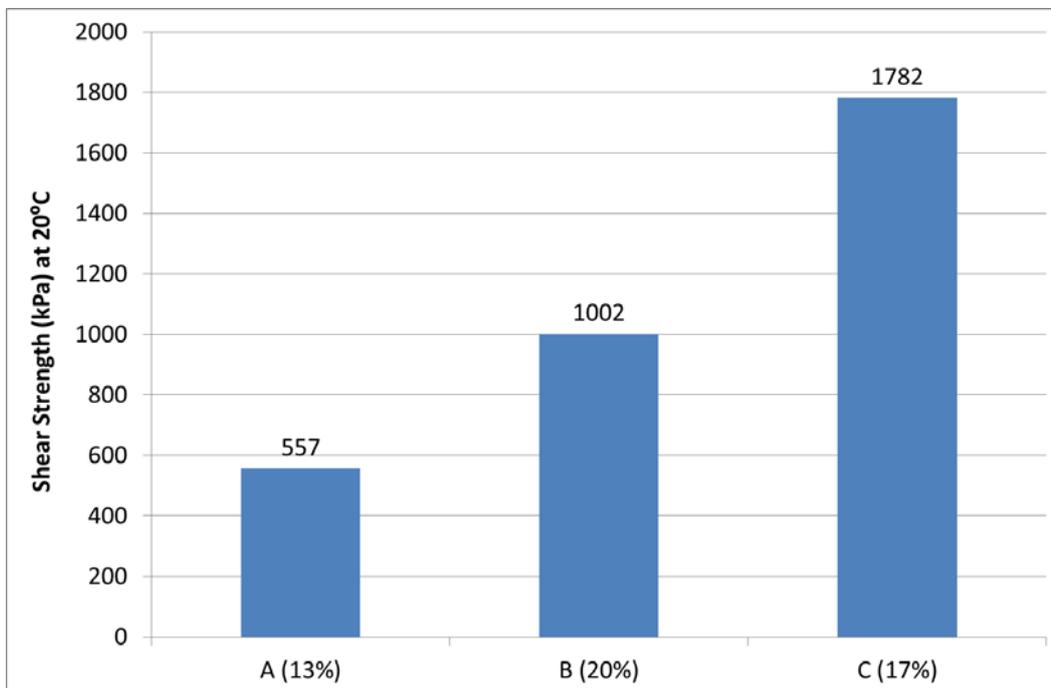
The results in Table 7 confirm the successful application of the “pre-heated test disc” to the newly applied HFS, both in situ and in laboratory. The results show reasonably repeatable τ_{SBS} values which predominantly exceeded 1600 kPa when tested at ambient temperatures (between 16 and 22°C).

The SBS test is able to show the effect of variations in the binder contents of HFS samples (see Figure 7), which for the systems tested showed a strong relation to the ITS test (see Figure 8).

Samples presented in Figure 7 are:

- A with 13% low binder content
- B with 20% rich binder content
- C with 17% the correct binder content and this is a BBA/HAPAS approved product

Amongst these samples, the optimum binder content was 17% and the SBS results suggest that the strength of HFS may reduce by more than half where there were more than 3% variations in the binder contents.



Note: figure in parentheses denote binder contents

Figure 7: The effect of binder contents to SBS values

3.2.3 ITS development

The Indirect Tensile Strength test is often used in asphalt testing to determine its resistance against tensile cracks. Cylinders of HFS were manufactured and tested in order to understand if any correlation could be made between binder quantities and tensile strength results.

The same mix designs as those samples presented in Figure 7 were adopted for the ITS testing, specifically:

- A with 13% low binder content
- B with 20% rich binder content
- C with 17% the correct binder content and this is a BBA/HAPAS approved product

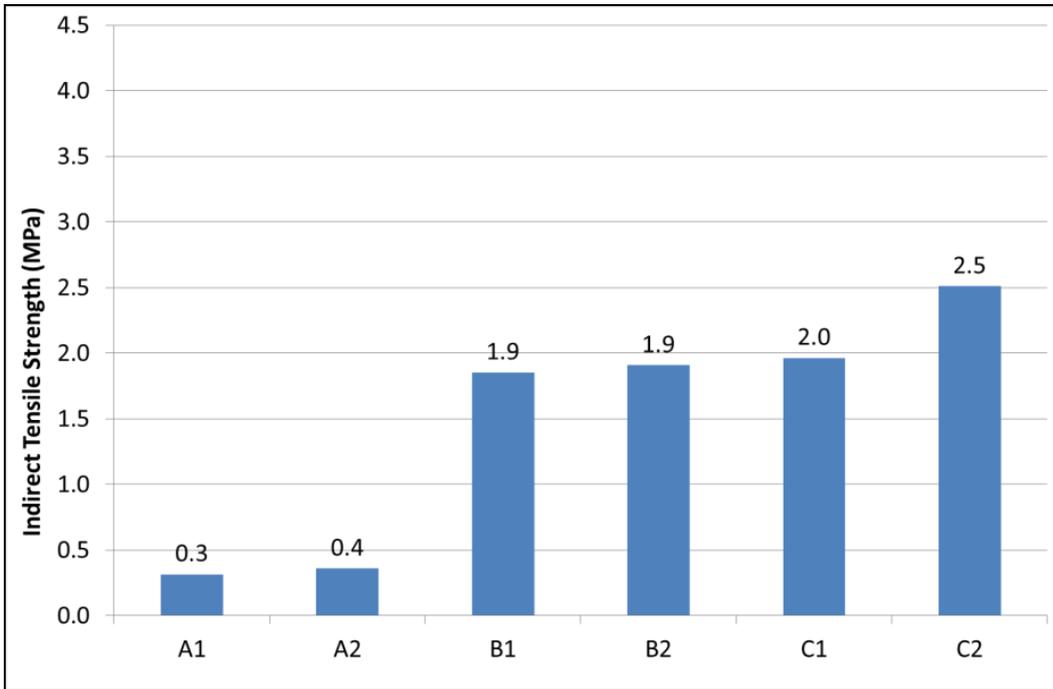


Figure 8: Indirect Tensile Strength results for various binder content samples.

Results in Figure 8 show that there was a distinctive difference between the various binder contents in A, B and C. ‘A’ demonstrated very low tensile strength due to the low percentage of binder added to the mix whereas B demonstrated high tensile strength but indicates that too much binder was used in comparison to mixture C at 17% binder content.

The equipment required to carry out the test is already widely available and the only adaptation to its current specification is the dimensions of the cylinder, which will be 100mm diameter and 50mm thickness.

3.3 Suggested Acceptance Criteria

Based upon the above suite of in situ and laboratory assessments, the acceptance criteria are proposed as:

- SSS of the material (either in situ or in laboratory):
 - For the HFS, the τ_{SSS} should not less than 1.5MPa when tested at ambient temperatures;
 - For the asphalt Substrate, the τ_{SSS} should not less than 1.0MPa when tested at ambient temperatures up to 35°C.
- SBS between the HFS and the asphalt substrate (either in situ or in laboratory):
 - The τ_{SBS} should not less than 1.0MPa when tested at ambient temperatures up to 35°C.
- ITS of the HFS (for laboratory testing)
 - The ITS value at 20°C should not less than 1.5MPa.

3.4 Summary of Findings and Recommendations

The SBS test allows a pavements current surface to be tested for suitability of HFS application prior to full installation. If at this point the pavement is deemed unsuitable then it is possible to rectify the pavements surface quality prior to installing a HFS, as otherwise the new surfacing may delaminate as a result of application onto an unsuitable surface. ITS testing can determine the consistence of material's strength; this value may assist identifying poorly mixed material, over cooking and incorrect mix ratios (lack of or excessive binder).

Based upon the findings from this study, the following recommendations are proposed for inclusion in the specification for highway works:

- 1) During the mix design stage:
 - a. SSS testing should be performed on HFS samples;
 - b. ITS testing should be performed on HFS samples.
- 2) During installation:
 - a. SSS testing (in situ) should be performed on the existing asphalt substrate prior to overlaying with HFS;
 - b. SBS testing (in situ) between HFS and asphalt substrate should be performed;
 - c. If there is a weather or access restrictions to carry out the above in situ testing, the test can be carried out in laboratory on core samples taken from site;
 - d. ITS testing (in laboratory) should be performed on HFS sub-samples.
- 3) SBS testing between HFS and asphalt substrate should be performed at the end of guarantee period.

The methods to carry out the above tests are presented in Appendix B of this report.

Table 8 presented some proposed performance categories that can be considered for inclusion in a highways specification.

Table 8: High Friction Surfacing Performance Categories

Characteristics required				
Technical requirement	Reference	Unit		
Visual assessment of defects			Defects in the inside wheel track ^{NOTE 1}	Defects in the outside wheel track ^{NOTE 1}
P_1 – fatting up to 2 weeks and any time up to 2 years	BS EN 12272-2	%	≤ 0.5	≤ 2
P_2 – delamination at 2 years	BS EN 12274-8 ^{NOTE 2}	%	≤ 0.5	≤ 2
P_3 – fretting at 2 years	BS EN 12272-2	%	≤ 3	≤ 6
P_4 – grinning at 2 years	BS EN 12274-8 ^{NOTE 2}	%	≤ 3	≤ 6
NOTE 1 where the location of the wheel track is indeterminate, as on roundabouts, the whole area shall meet the wheel track criteria.				
NOTE 2 the assessment is carried out using two separate standards surface dressing and microsurfacing, because the failure mechanisms for HFS include delamination and wear				
NOTE 3 where cracking is a defect then it is necessary to consider untreated substrate condition and photographic records are useful				
Surface characteristics				

Initial macrotexture minimum	BS EN 13036-1	mm	≥ 0.8 for individual measurement and ≥ 1.0 mean	
Macrotexture minimum up to 2 years	BS EN 13036-1	mm	≥ 0.5 for individual measurement and ≥ 0.8 mean	
Bond to substrate				
In situ test for HFS systems	prCEN/TS 12697-51 ^{NOTE 4}		$\tau_{SSS} \geq 1500$ kPa ; or Peak Torque ≥ 340 Nm	
In situ test for asphalt substrate (prior to installation of HFS systems)	prCEN/TS 12697-51 ^{NOTE 4}		$\tau_{SSS} \geq 1000$ kPa ; or Peak Torque ≥ 220 Nm	
In situ test for bond between HFS system and asphalt substrate at the end of 2 years	BS EN 12697-48 ^{NOTE 5}		$\tau_{SBS} \geq 1000$ kPa ; or Peak Torque ≥ 220 Nm	
NOTE 4 in situ test need not use coring				
NOTE 5 in situ test needs coring to 20mm below the interface with the asphalt substrate				
Screed Strength for Hot Applied and Cold Mixed HFS				
Mixed materials test: samples from site prepared from production, cast 100 mm diameter 50 mm thick (see protocol)			Category 1 Hot Screeded	Category 2 Cold Screeded
Indirect Tensile Strength (cohesive) at 20 C	BS EN 12697-23	GPa kN	$\geq 15E-04$ 10 Peak load	$\geq 50E-04$ 40 Peak Load
Chippings: PSV, AAV, Grading	BS EN 13043	Declared, if not to Calcined Bauxite Specification		
Binder of thermoplastic systems	BS EN 1427	Softening Point Declared		
Binder of both thermoplastic and cold systems	IR Spectroscopy	Declared		
Other Characteristics				
High Friction Surfacing System	System: cold applied thermosetting broadcast; hot thermoplastic screeded; or cold thermosetting mixed screeded system.			
Installation				
Target rate of spread of binder for cold applied broadcast systems	BS EN 12272-1	kg/m ²	Declared	
Tolerance on rate of spread of binder – for cold applied broadcast systems	BS EN 12272-1	%	± 10	
Target application rate for screeded systems hot and cold	BS EN 12274-	kg/m ²	Declared	

Tolerance on rate of spread of mixed material – for cold applied broadcast systems	BS EN 12274-6	%	± 15
Target binder content for hot screeded thermoplastic resins	BS EN 12697-39	%	Declared
Tolerance on target binder content	BS EN 12697-39	%	± 10
Other characteristics of constituents			
Binders Other characteristics of binders may be declared			
Aggregates – Calcined Bauxite Other characteristics of aggregates may apply according to BS EN 13043 as appropriate			

4 COLD APPLIED BROADCASTED HFS

A revised protocol has been reviewed and submitted to BBA in January of 2015. Feedback was received from BBA in March of 2015 which was incorporated into the revised version of the protocol. The protocol included an adaptation of the scuffing test, whereby a sample was placed under repeated scuffing action and its loss of aggregate measured in accordance with the Erosion Index developed specifically for this test. Details are presented in Procedure D of Appendix B.

Previous work (HA Framework Contract 136(4/45/12)ARPS) has identified the limitation of the test method for assessment of HFS incorporating thermoplastic binders and consequently the current study has restricted the use of scuffing test for assessing non-thermoplastic HFS, specifically cold applied broadcast systems.

4.1 Sourcing of Materials

Suppliers were approached with the request to provide cold applied high friction surfacing to asphalt slabs. Both suppliers A and B were able to provide the necessary services.

Supplier A

A lab visit was arranged whereby the variables of HFS application were discussed.

It was agreed that factors causing the variable site issues could involve:

- Surface water
- Improper (lack of) use of a Scratch coat.

Supplier B

Supplier B provided 4 standard samples and 2 sub-standard samples whereby they have reduce the curing agent and/or the binder content, as may occur on site.

4.2 Test Houses

Thameside Test and Research (TTR) and PTS laboratories were able to offer scuffing testing and were willing to work with the projects aim.

4.3 Sample Variables

Supplier A

Variable 1, surface water.

Surface water should not be present during the application of a cold applied HFS as this will affect the bond between the binder and the asphalt potentially inducing delamination.

Variable 2, Scratch coat

A scratch coat is applied whereby it is decided that the macro texture of the asphalt surface is too great for the proper application of the HFS resin. It is essentially a fill/leveller for the resin to adhere to prior to application of the bauxite.

Supplier A agreed to coat the 6 slabs as follows:

- 2x slightly wet of which 1x with Scratch coat 1x without scratch coat;

- 4x dry slabs of which 3x with scratch coat applied and 1x without.

Thus comparing

- A sample with scratch coat, wet and dry.
- A sample without scratch coat, wet and dry.
- And comparing dry samples with and without scratch coat.

These samples were tested at 2 separate laboratory testing facilities, and they were not aware of the different conditions at which the HFS was applied.

4.4 Comparative results obtained by two laboratories

During the first round assessment, each laboratory (test house 1 or 2) carried out the scuffing test and the subsequent post-scuffing assessment (EI and texture depth). For the second round, images of surface of the samples after scuffing were exchanged and sent to the other laboratory and the EI assessment was repeated using the images. The results are summarised in Table 9.

Table 9: Round-robin scuffing test

Sample ID	Asphalt condition	Scratch coat	Loss of texture depth (%)	Test house code	Erosion Index 1 st round	Repeat EI 2 nd round
A1	Dry	Yes	24	1	0	0
A2	Wetted then dried	Yes	10	2	2	2
A3	Dry	No	25	1	0	0
A4	Wetted then dried	No	29	1	0	0
A5	Dry	Yes	14	2	0	0
A6	Dry	Yes	5	2	2	0
B1	Standard	No	24	1	0	0
B2	10% extra part B	No	25	1	0	0
B3	10% less part B	No	31	1	1	2
B4	Standard	No	20	2	0	0
B5	Standard	No	5	2	1	0
B6	Standard	No	17	2	0	0

The results in Table 9 suggest that:

- There was a large variability in the texture depth measurements and these were considered due to the space restriction from carrying out the test on surfaces after scuffing. Therefore it is recommended that assessment of texture depth is only required before the scuffing test.
- Good repeatability in the visual condition assessment using EI, as shown by similar results from duplicate/triplicate samples from each round.
- Good reproducibility in the visual condition assessment using EI, as shown by consistent results from the first and second round assessments.

As stated above, images of the samples, post-scuffing, were sent to the alternate Laboratory to which the scuffing took place; this provided a second opinion on what the EI was for each sample. The main issue with this approach was that the images do not allow the 4 angle view required in the specification and therefore the assessor has limited data in comparison to the original assessor. However the results obtained were relatively comparable, as shown in Table 9.

The EI assessment did pick up variability within the samples however areas for improvement were identified, such as tightening up the EI banding system and that visual observations by two different assessors can provide a more representative view of the surface condition. For the former, a new “grade a” was introduced to account for area where the coating (including aggregate) retention after the scuffing test is greater than 90%. An illustration is presented in with details are available in Procedure D of Appendix B. For the latter, it is recommended that visual condition of the HFS after the scuffing test should be assessed by two people and the mean should be reported. In addition to this, photographs of the surface condition should always be taken, to complement the visual assessment.

Table 10: Assessment of rating of grid squares

Grade	Area of Coating (including aggregate) Remaining	Weighting Factor
a	Greater than or equal to 90%	x 0
b	Greater than or equal to 75% and less than 90%	x 0
c	Greater than or equal to 50% and less than 75%	x 1
d	Greater than or equal to 25% and less than 50%	x 2
e	Less than 25%	x 3

4.5 Summary of Findings

As a result of the initial testing it was not possible to determine the highest performing samples by EI, this was due to the majority of samples falling into the upper band of performance (more than 75% remaining), which was too broad. Samples that fell into this bracket were identified as the same EI performance even though there was a distinguishable difference, for example: sample **A** with 98% and sample **B** with 76% of its aggregates remaining, however both would receive an EI grading of 0. The new protocol would still provide an EI grading of 0, however it would have been noted that all squares on sample A were within the 90-100% retained band, thus identifying its higher performance.

The additional grading method can provide an option for the Highways England to introduce a requirement for premium HFS material that: the material must achieve an Erosion Index of 0 and all squares must be placed within the 90-100% retained band.

Appendix A

Liaisons with RSTA and RSMA

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Subject: HA Study on Understanding Durability of High Friction Surfacing (HSF)
Date: 22 May 2014 11:44:00

Re: Understanding Durability of High Friction Surfacing (HSF)

Dear Sirs

ARUP URS in association with Acland has recently been commissioned by the Highways Agency (project sponsor Donald Burton) to carry out a study to develop methods for assessment of durability of High Friction Surfacing (HFS).

This work was set against a background that the current assessment method, known as scuffing test, was either requiring improvement or not suitable to assess the durability of various HFS types. The conclusion from a previous HA study, Task 136, reported that:

- (a) Whilst the scuffing test method can provide some indication of durability of spray applied (cold) HFS, large variability (repeatability and reproducibility) in test results was reported between different BBA HAPAS approved laboratories. Improvement to this method was recommended.
- (b) On the other hand, the scuffing test method was considered not suitable for assessing durability of hot screed applied HFS. Alternative test methods should be researched or developed.

We would like to invite members of RSMA and RSTA to participate to this study by providing us with technical information and if possible some free samples to cover the range of materials. We would be grateful if you could kindly forward our invitation to your members.

Stage 1 - Technical Information

After receiving a list of interested HFS manufacturers, we would initiate contact to learn their view and experience on the current test method, and any ideas for alternative tests to evaluate durability. If requested, we could treat the information in confidence.

Stage 2 - Provision of free HFS samples for testing

Within the scope of this study, we have allocated 4 sets of HFS materials to be trialled and assessed using the new or modified method(s) at no cost to the material suppliers, under the following conditions:

- If there are more than 4 materials being proposed by the suppliers, we will shortlist them and select 4 representative sets.
- The identity of the samples selected for testing will only be known by the URS register and the respective suppliers, otherwise unique numbers will be allocated for these samples and they will be made anonymous in our reports and discussions.
- If other suppliers whose materials are not selected for testing would like to be included in this study, they would be requested to cover the cost for testing and need to meet a deadline for supply of material.

At the end of this study, both RSTA and RSMA will receive an electronic copy of the final report presenting the findings from this study. Our aim is to complete this study by end of March 2015.

We trust the above clearly presents our programme of assessments. This study was started

early this month and we are aiming to start making direct contacts to gather and compile all technical information in June, and therefore would be grateful to receive your feedback or confirmation of participation to this study before 9 June please.

Please do not hesitate to contact me if further detail is required.
I will be away overseas on business for the next two weeks but will be checking my emails to respond to your queries if any.

We look forward to hearing from you.

Kind regards

Daru

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Appendix B

Proposed New Test Methods for HFS

Test Methods for High Friction Surfacing

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Test Methods for High Friction Surfacing

1 Scope

This standard describes a suite of test methods to assist in determining the suitability of a hot or cold applied screeded High Friction Surfacing (HFS) at a specific location. It details testing of the HFS mixture itself, the HFS's surface shear strength after application and also its adherence to the existing road surface. The tests are titled 'Indirect Tensile Strength (ITS)', 'Surface Shear Strength (SSS)' and 'Shear Bond Strength (SBS)'.

Annex E presents an additional test specifically for cold applied, non-thermoplastic material.

2 Terms and definitions

For the purposes of this Standard, the following terms and definitions apply.

2.1 Surface Shear Strength – Durability test

A combination of the rotational shear strength between HFS and the asphalt substrate, the torsional strength around the circumference of loading within the high friction surface and, possibly, the torsional strength around the circumference of loading within the asphalt substrate.

2.2 Shear Bond Strength – Investigatory test

The rotational shear strength at the interface between HFS and the asphalt substrate.

Test Methods for High Friction Surfacing

2.3 Indirect Tensile Strength

Refer to BS EN 12697-23, HFS samples should be 50mm thick ± 5 mm

2.4 Surface course

The top layer of an asphalt pavement, designed to carry moving traffic.

2.5 High Friction Surfacing

High Friction Surfacing is a surface treatment applied in critical locations to increase the skid resistance of the pavement.

2.6 Hot disc application method

This describes a method of applying the test discs to the hot applied HFS by means of heating the metal test disc to a temperature within $\pm 5^{\circ}\text{C}$ of the material and placing it onto the material requiring testing.

2.7 Adhesive application method

This is the method of applying the test discs to the sample material by means of an adhesive.

2.7.1 Hot applied screeded HFS should be allowed to harden prior to application of adhesive and disc.

2.7.2 Cold applied screeded HFS should be allowed to harden prior to application of adhesive and disc. If appropriate (after initial testing) the disc may be placed on the HFS prior to curing, using the cold binder material to create the bond.

3 Principle

In both SSS and SBS tests, a 100 mm diameter disc is bonded to the surface course and rotated using a torque meter to determine the torsional strength of the top layer and the rotational shear strength between layers. These tests can be carried out either in situ (temperature of not less than 15°C) or in the laboratory. The ITS test can only be carried out in the laboratory.

3.1 Surface Shear Strength

The High Friction Surfacing is placed on an asphalt surface, followed by the immediate application of the metal test disc which has been pre-heated to $\pm 5^{\circ}\text{C}$ of the HFS material. The disc should be firmly placed on the surface without causing excessive displacement of the hot applied HFS material, however the mixture should prevent this. This test may be suitable to conduct trials during application of a HFS material and also ex-situ laboratory trials after ageing or curing, in this context the core shall have a minimum of 200mm diameter and 50mm thick. If initial trials/tests identify that the 'hot metal disc application' method for hot applied screeded HFS is not sufficient (where failure at HFS/metal disc interface measures at a value lower than the requirements) then a structural adhesive may be used as an alternative, however this requires longer curing times (see section 5).

NOTE 1: The surface shear strength will depend on material preparation. Inadequate mixing of components or mixing for prolonged periods of time can adversely affect the performance of the material. Prolonged heating of hot applied HFS or excessive temperatures greater than recommended by the manufacturer can cause the material to become brittle, thus reducing its performance.

NOTE 2: The failure mode for this type of testing can be varied; this is mostly affected by the HFS/Asphalt bond, and the strength of the HFS itself. Failure may occur in a perfect circle around the circumference of the test disc

Test Methods for High Friction Surfacing

or irregularly, dependent on the homogeneity of the material and the regularity of the underlying surface course.

3.2 Shear Bond Strength

The high friction surfacing is placed in a strategic location in order to test the materials adherence to the asphalt surface prior to the application of a large section. The shear bond strength will depend on the asphalt substrate type and condition together with the adherence properties of the HFS material. The test is particularly susceptible to surface course temperature as the binder within the asphalt substrate (depending on its age) may soften more than that of the HFS material.

The material should be prepared and mixed adequately prior to being poured into the centre of three heated (if carrying out hot disc application method) 105mm internal diameter steel collars. The collar should be shallow enough to conduct the testing without the need to remove it, Figure 3.2.1 illustrates the above.

For the hot disc method, after the material is placed into the collar, immediate application of the metal test disc pre-heated to $\pm 5^{\circ}\text{C}$ of the hot applied HFS material is required. The disc should be firmly placed into the collar to ensure adequate contact with the material.

For the adhesive method the material may be placed and then allowed to cool or cure prior to application of the adhesive and the test disc.

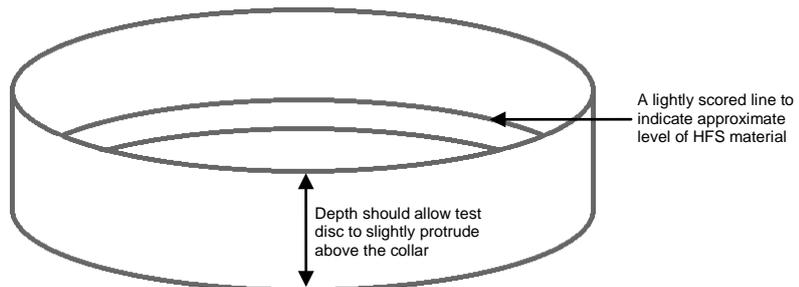


Figure 3.2.1 : Illustration of HFS confinement collar

3.3 Indirect Tensile Strength

The cylindrical specimen to be tested is brought to the specified test temperature, placed in the compression testing machine between the loading strips, and loaded diametrically along the direction of the cylinder axis with a constant speed of displacement until it breaks. The indirect tensile strength is the maximum tensile stress calculated from the peak load applied at break and the dimensions of the specimen, refer to BS EN 12697-23.

4 Apparatus and Materials

4.1 Torque meter, fitted with a reading gauge that indicates the maximum torque obtained. The device shall be calibrated over a range of not less than 400 Nm with a scale accurate and readable to at least 20 Nm. The device shall be fitted with a socket fitting allowing steel discs to be fitted and removed.

NOTE 1: Greater capacity eg. 800Nm may be required for design purposes and measuring asphalt substrates.

4.2 Metal discs, each having a diameter of 100 mm and a thickness of (14 ± 2) mm. The disc shall incorporate a fitting enabling it to be coupled to the torque meter.

Test Methods for High Friction Surfacing

NOTE 2: Mild steel has been found suitable for the disc.

4.3 Thermometer, capable of measuring temperatures from room temperature to 100 °C, readable to 0,1 °C and accurate to 0,5 °C.

4.4 Mould and collar, made of steel with an internal diameter of 100mm and 105mm respectively.

4.5 Oven, for conditioning samples (laboratory testing only)

4.6 Adhesive, structural adhesive with a shear adhesive strength on steel or etched aluminium of 3500psi at 77°F/25°C

4.7 ITS apparatus, refer to section 5 of EN 12697-23:2003

4.8 Coring apparatus, if required for laboratory testing, with minimal vibration and the ability to extract cores of 200mm diameter for SSS and 100mm diameter for SBS.

5 Procedure

5.1 Site

The location to be tested, either in situ or where cores are to be taken for laboratory testing, shall be visually uniform in texture and visibly free of detritus and oil deposits; if this is not possible, and this is the case across the site, visual appearance shall be recorded.

5.2 In situ procedure for Surface Shear Strength

5.2.1 This test may be carried out on a test section newly laid material or on existing sections to test the Surface Shear Strength.

5.2.2 The section area for testing and the number of tests within each section should be defined depending on the importance of the site in terms of traffic and use

5.2.3 For cold or hot applied screeded HFS and existing HFS surfaces the adhesive application method should follow the recommendations in section 2.7.

5.2.4 Upon applying the metal disc take care to ensure that it is parallel to the surface and locate three metal discs, placed within 1 m of each other and at least 100 mm apart at each location of testing.

5.2.5 When using the hot disc method, ensure that it is placed immediately after applying the HFS, this will ensure greater adherence between the disc and HFS, upon cooling to ambient proceed from 5.2.8.

5.2.6 If using an adhesive to adhere the disc to the HFS ensure sufficient time is allowed for curing. If it is not possible to close the road for the duration of the curing, specially designed discs may be used however the dimensions must be in accordance with clause 5.2 of BS EN 1463-1:2009.

5.2.7 When the adhesive has developed sufficient strength to avoid a failure occurring within the adhesive, proceed as follows.

5.2.8 Connect the torque meter to the metal disc, using adaptors as appropriate.

5.2.9 Record the temperature to $\pm 0,5$ °C at approximately the interface between the HFS and the asphalt substrate by drilling a hole 3-7 mm deep at the location of testing. If the temperature is less than 15°C then a 200mm diameter core should be extracted for laboratory testing, this should be carried out as detailed in section 5.5.1.

Test Methods for High Friction Surfacing

5.2.10 Apply torque to the metal disc at a steady rate so that the torque wrench would sweep an angle of 90° within (30 ± 15) s. Care shall be taken to ensure that the torque is applied parallel to the surface within $\pm 10^\circ$. Torque should be applied to the disc until failure occurs or a torque greater than the minimum requirement as declared in the acceptance criteria.

5.2.11 Record the value of torque at failure, M , in Newton metres.

5.2.12 Examine the material adhering to the metal disc and the resulting failure plane in the pavement. Record:

- Shape of the material both horizontally and vertically
- If the material has removed any of the asphalt surface, record characteristics and depth.
- If the material has sheared away within itself record visually the percentage of HFS mixture material on disc that is not asphalt.

5.3 In situ procedure for determining the Shear Bond Strength of a hot applied screeded HFS using the hot disc application method



Figure 5.3.1 Flow chart demonstrating method for SBS testing using hot disc application method.

5.3.1 Using a heated 105mm internal diameter collar pour the HFS into the centre to provide 4 mm to 6 mm thick sample, trim any excess material which flows under the collar.

5.3.2 The pre-heated test disc should then be placed immediately into the collar, on top of the HFS material; pressure should be applied in order to attain good contact.

5.3.3 Both the collar and the disc should be heated to $\pm 5^\circ\text{C}$ of the HFS mixture temperature. This is to allow the material to level and make good contact with the disc prior to cooling.

5.3.4 Take care to ensure that the disc is parallel to the surface.

5.3.5 At each testing location there should be three collars surrounding the HFS material and metal discs, placed within 1 m of each other and at least 100 mm apart.

5.3.5.1 The section areas can also be determined dependent on the regularity of the surface in the proposed location. It is important to test all surface types and particularly areas which show signs of distress.

5.3.6 When the material has cooled down to 20°C , connect the torque meter to the metal disc using the adaptor. There is no need to remove the collar unless it has been lubricated beforehand and is possible without disturbing the sample.

5.3.7 Record the temperature to $\pm 0.5^\circ\text{C}$ at approximately the interface between the adhesive and the surface course by drilling a hole of 3-7 mm deep at the location of testing. If the temperature is less than 15°C then a 100mm diameter core should be extracted for laboratory testing, this should be carried out as detailed in section 5.5.1.

5.3.8 Apply torque to the metal disc at a steady rate so that the torque wrench would sweep an angle of 90° within (30 ± 15) s. Care shall be taken to ensure that the torque is applied parallel to the surface to within $\pm 10^\circ$. Apply the torque to the disc until failure occurs or a torque of 400 Nm is exceeded.

5.3.9 Record the value of torque at failure, M , in Newton metres.

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5.3.10 Examine the material adhering to the metal disc and the resulting failure plane in the pavement.
Record:

- If any asphalt has been pulled away, record characteristics/shape and depth.
- If the material has sheared away within itself record visually the percentage of material on disc that is not asphalt.

5.4 In situ procedure for determining the Shear Bond Strength of Hot and cold applied screeded HFS using the adhesive application method



Figure 5.3.1 Flow chart demonstrating method for SBS testing using adhesive application method

5.4.1 Pour the HFS into the centre of an internally lubricated 105mm internal diameter collar, enough material should be provided to allow a 4 mm to 6 mm thick sample

5.4.2 Allow the material to cool (in the case of hot applied) or cure (in the case of cold applied)

5.4.3 Adhere the test disc to the HFS surface, taking care to ensure that the disc is parallel to it.

5.4.4 There is no need to remove the collar if the road is closed during curing, however if this is not possible then the collar should be removed after sufficient curing allows.

5.4.5 If the collar is removed due to no road closure being available during curing then specially designed discs may be used if the dimensions are in accordance with clause 5.2 of BS EN 1463-1:2009

5.4.6 When the adhesive has developed sufficient strength to avoid a failure between the HFS material and the test disc, fit the torque meter to the metal disc using the adaptor.

5.4.7 Record the temperature to ± 0.5 °C at approximately the interface between the adhesive and the surface course by drilling a hole of 3-7mm deep at the location of testing. If the temperature is less than 15°C then a 100mm diameter core should be extracted for laboratory testing, this should be carried out as detailed in section 5.5.1.

5.4.8 Apply torque to the metal disc at a steady rate so that the torque wrench would sweep an angle of 90° within (30 ± 15) s. Care shall be taken to ensure that the torque is applied parallel to the surface within $\pm 10^\circ$. Apply the torque to the disc until failure occurs or a torque of 400 Nm is exceeded.

5.4.9 Record the value of torque at failure, M , in Newton metres. Any interface that comes apart during preparation shall be noted.

5.4.10 Examine the material adhering to the metal disc and the resulting failure plane in the pavement.
Record:

- If any asphalt has been pulled away, record characteristics/shape and depth.
- If the material has sheared away within itself record visually the percentage of material on disc that is not asphalt.

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5.5 Laboratory procedures

5.5.1 SSS and SBS

5.5.1.1 Three 200mm diameter cores should be extracted for the SSS testing and three 100mm diameter cores should be extracted for the SBS testing, both in accordance with EN 12697-27. The cores shall not be less than 50 mm thick, the coring machine and core cutter shall be such that there is minimal vibration to avoid disturbing/damaging the HFS.

5.5.1.2 The cores shall be removed carefully. Discard any cores that are damaged during removal if the damage impinges into the central 100 mm diameter area or the edge is damaged by at least 6 mm. Record any other damage.

5.5.1.3 If it is not possible to condition and test the cores within 48h they shall be transferred to storage within 48 h and stored at a temperature of 0 °C to 5 °C.

5.5.1.4 Examine each core in accordance with BS5930:1999 + A2:2010 and record the HFS thickness

5.5.1.5 Trim the cores to a length suitable for mounting if appropriate.

5.5.1.6 Place the core in the clamp.

5.5.1.7 Use the adhesive to secure the metal disc to the surface of the core, taking care to ensure that the disc is parallel to the surface. Leave at ambient temperature until the adhesive has developed sufficient strength to avoid a failure occurring within the adhesive.

5.5.1.8 Store the mounted core at the selected temperature, either (35 ± 2) °C or (20 ± 2) °C, for at least 4 h. start the test not less than 16 h from the assembly or conditioning to the start of the test. Record the storage time and temperature of test.

5.5.1.9 Fix or clamp the collar containing the mounted core to a suitably rigid horizontal surface. Fit the torque meter to the metal disc, using adaptors and extension rods as appropriate.

5.5.1.10 Apply torque to the metal disc at a steady rate so that the torque wrench would sweep an angle of 90° within (30 ± 15) s. Care shall be taken to ensure that the torque is applied parallel to the core surface to within $\pm 10^\circ$. Apply the torque to the disc until failure occurs or a torque of 400 Nm is exceeded.

5.5.1.11 The test shall be completed within 5 min of removal from storage.

5.5.1.12 Record the value of torque at failure, M , in Newton metres. Any interface that comes apart during preparation shall be noted.

5.5.1.13 Examine the material adhering to the metal disc and the resulting failure plane in the pavement. Record:

- the shape of the failure plane (conical, essentially horizontal, irregular etc.);
- the condition of the failure plane (smooth, planar, rough, etc.);
- the extent of the failure in the material surrounding the metal disc;
- the maximum depth of the failure plane below the top surface of the asphalt.

5.5.1.14 Repeat 5.4.1.5 to 5.4.13 for each specimen.

5.5.2 ITS

5.5.2.1 Manufacture specimens on site by placing material into pre-heated 100mm diameter moulds with a height of 50 ± 5 mm. for hot applied screeded HFS, these moulds shall be preheated to a temperature $\pm 5^\circ\text{C}$ of the material prior to receiving the material. Specimens shall undergo conditioning and testing within 48

Test Methods for High Friction Surfacing

hours of manufacture, if it is not possible to complete within 48 h materials may be stored between 0-5°C for a maximum of 14 days.

5.5.2.2 Conditioning shall comply with section 7 of EN12697-23; the test temperature shall be 20°C.

5.5.2.3 Test procedure shall be carried out in accordance with section 8 of EN12697-23.

6 Calculation and expression of results

6.1 SSS and SBS

6.1.1 Calculate the SSS and SBS for each specimen in kilopascals (KPa) using the following formula:

$$\frac{12 \times M \times 10^6}{\pi \times D^3} \quad (1)$$

Where:

- M* is the peak value of applied torque, in Newton metres (Nm);
D is the diameter of the metal disc, in millimetres (mm).

6.1.2 Calculate the arithmetic mean of the shear bond strength, *SBS* or *SSS*, for the three specimens.

6.1.3 The *SBS* may be used to determine an existing pavements suitability to receive the High Friction Surfacing.

6.1.4 The *SSS* may be used to determine the High Friction Surfacing's ability to resist internal shearing.

6.2 ITS

6.2.1 Calculations shall be carried out in accordance with section 9 of EN12697-23.

6.2.1.1 Results may be compared to laboratory manufactured samples in order to gauge any loss of strength due to manufacturing on site.

7 Test report

7.1 SSS and SBS

With reference to this Standard, the test report shall include the following information:

- a) name and address of the testing laboratory;
- b) a unique serial number for the test report;
- c) date of the test;
- d) identification of site or scheme, core or in situ test locations and any anomalies in visual appearance;
- e) method of test used (in situ, laboratory);
- f) storage details (duration and temperature);
- g) the HFS material type and nominal aggregate size;
- h) the surface course material type, maximum aggregate size and, if known, depth and age;

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- i) the shape of the failure plane (conical, essentially horizontal, irregular etc.) for each location (in situ) or specimen (laboratory);
- j) the condition of the failure plane (smooth, planar, rough, etc.) for each location (in situ) or specimen (laboratory);
- k) the extent of the failure in the material surrounding the metal disc for each location (in situ) or specimen (laboratory);
- l) the maximum depth of the failure plane below the top surface of the asphalt for each location (in situ) or specimen (laboratory);
- m) the mode of failure for each location (in situ) or specimen (laboratory);
- n) temperature at the bond interface or of the HFS dependent on failure location to nearest 0.5°C;
- o) the peak torque at failure in Nm for each location (in situ) or specimen (laboratory);
- p) the time to failure in s for each location (in situ) or specimen (laboratory);
- q) shear bond strength in KPa for each location (in situ) or specimen (laboratory) and mean values and whether they are:
 - in situ at 20 °C or laboratory at 20 °C,
 - laboratory tested at 35 °C
 - other temperature.
- r) any damage to the cores;
- s) any other anomalies.

7.2 ITS

7.2.1 Test report shall be carried out in accordance with section 10 of EN12697-23: 2003.

8 Precision

8.1 SSS and SBS

The precision for this test method has not been determined.

8.2 ITS

8.2.1 Details on the precision of this test are available in section 11 of EN12697-23: 2003

Test Methods for High Friction Surfacing

Annex A
(informative)

Example of Hot Disc Method with collar removed



Annex B
(informative)

Example Failure within HFS and SMA substrate



Note: HFS has sheared both through itself and also at the interface with the asphalt substrate; a thermocouple can be seen recording the temperature.

Annex C
(informative)

Example Failure within SMA substrate

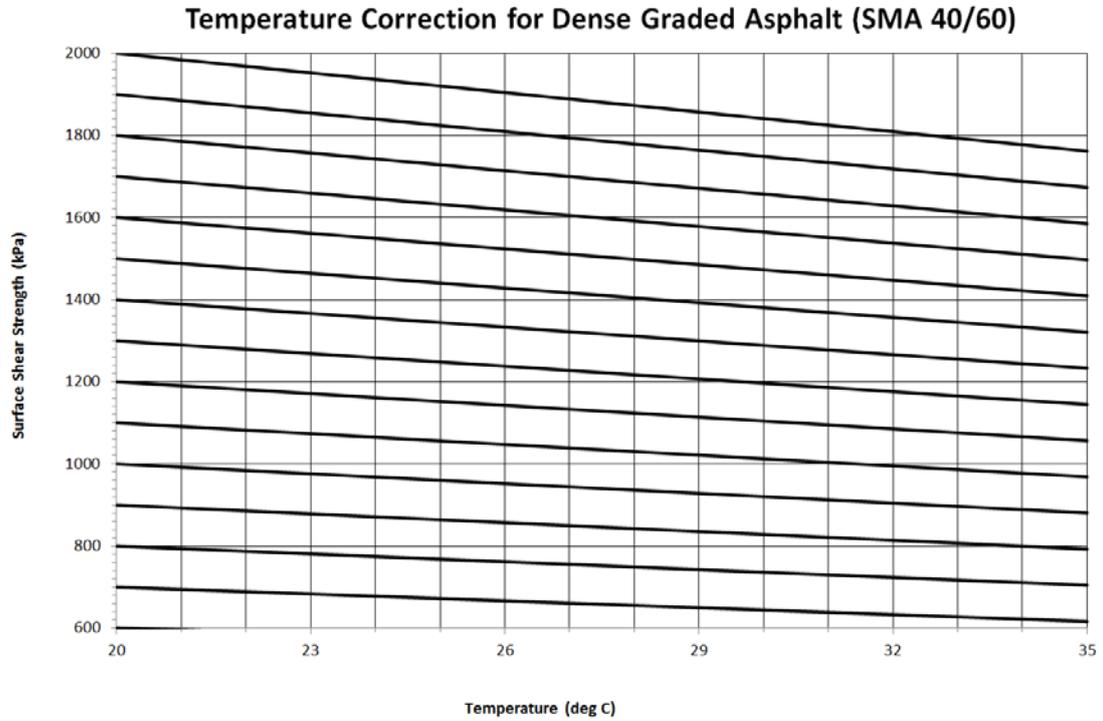


Test Methods for High Friction Surfacing

Annex D (informative)

Illustration of a temperature correction factor for an SMA substrate

Correction factors may be developed for different substrates for in situ testing



Annex E

Scuffing test for cold applied non-thermoplastic material

1. Scope

The scuffing test for cold applied High Friction Surfacing (HFS) is designed to simulate the braking and turning action of traffic by eroding aggregate and also to assess the potential bond to asphalt road surfaces. The test is not suitable for thermoplastic materials, including hot applied HFS.

Cold applied HFS consists of an even application of a proprietary cured resin binder (usually epoxy, bitumen extended epoxy, acrylic, polyurea or polyurethane resin) onto a prepared road surface, followed by application of high polishing and abrasion resistance aggregate.

Calcined bauxite, typically consisting of 1-3mm granular clean chippings, has been the most commonly used artificial aggregate, due to its high resistance to abrasion and a very high resistance to polishing (PSV 70+). However, other natural and artificial aggregates may also be used.

2. Definitions

2.1 *Erosion Index (EI)*

Is a visual assessment of the proportion of material eroded by the scuffing test.

- 2.1.1 The highest weighting of 30 is given if less than 25% of the HFS material is retained in the area assessed, revealing the asphalt slab.
- 2.1.2 Where greater than 75% of material is completely retained a weighting of zero is given.
- 2.1.3 Where greater than 90% of material is completely retained a weighting of zero is given and if this score is obtained for all grid squares, this material may be considered as a premium product.
- 2.1.4 Where aggregate is visible but punched in to the binder, this is not regarded as loss.

2.2 *Wheel Tracking Machine*

BS EN 12697-22 Bituminous Mixtures – Test methods for hot mix asphalt – Part 22. Wheel tracking machine is used with some modifications and a different tyre.

2.3 *Bond*

Is the adherence of the applied binder to the asphalt substrate. Delamination occurs when the bond is broken so that binder with aggregate detaches.

3 Summary of test method

3.1 A loaded pneumatic-tyre wheel with its axle set at an angle to the direction of motion is repeatedly passed over the surfacing of a specimen at the selected test temperature: (45°C ± 1°C) for Type 1 and Type 2 and (35°C ± 1°C) for Type 3.

Note 1: Types 1, 2 & 3 are specified for different intended uses considering maximum traffic levels (commercial vehicles per lane per day) and site severity. Table NG9/24 of MCHW, Volume 2, 2008 provides such a specification.

3.2 The Erosion Index determined after a set number of passes is used as a measure of the resistance of the HFS to scuffing.

4 Apparatus

4.1.1 *Scuffing-wheel apparatus*, consists of a loaded wheel which bears on a specimen held in a moving table. The table moves to and from beneath the wheel with the axle of the wheel

held at an angle of $20^\circ \pm 1^\circ$ to the vertical plane perpendicular to the direction of travel. Vertical play in both the loaded wheel bearings and the lever arm pivot point shall be less than 0.25mm. A typical layout is shown in **Figure 1**.



Figure 1: Scuffing Test Equipment

4.1.2 *Pneumatic tyre*, of outside diameter of $215\text{mm} \pm 2.5\text{mm}$ when inflated to the test pressure, fitted to the wheel. The tyre shall be inflated to $3.1\text{bar} \pm 0.2\text{bar}$ (45psi) and have a ribbed tread of not less than 1.0mm

Note 2: Occasionally tyres when inflated to the test pressure may slightly exceed the specified diameter, when this occurs they should be rejected. The diameter has a direct effect on the scuffing action.

The tyre shall be visually inspected prior to each use. If the tyre tread that is to be utilised during the test appears filled with debris, the tyre shall be cleaned to restore the tread depth or replaced by a new clean tyre. The tyre may be rotated to enable the remaining tread satisfying the requirement to be used.

Note 3: The tyre tread is worn on less than a third of the circumference

4.1.3 *Weighted cantilever arm*, to apply a load to the wheel under standard test conditions of $520\text{N} \pm 5\text{N}$, measured at the level of the top of the specimen and normal to the plane of the sample table.

Note 4: The higher load used in BS EN 12697-22 of 700N is thought to be too great for the test and could damage the equipment and would need extensive correlation work.

4.1.4 *Sample table*, constructed so as to enable a $305\text{mm} \times 305\text{mm} \times 50\text{mm}$ laboratory prepared specimen to be held firmly in place with its upper surface horizontal, in the required tracking plane and with its centre positioned to ensure symmetrical tracking motion.

4.1.5 *Wheel-tracking machine*, constructed so as to enable the specimen to be moved backwards and forwards under the loaded wheel in a fixed horizontal plane. The centre of contact area of the tyre shall describe simple harmonic motion with respect to the centre of the top surface of the specimen with a frequency of 21 ± 0.2 load cycles (42 passes) per 60 seconds and a total distance of travel of $230\text{mm} \pm 5\text{mm}$.

Note 5: The frequency used in BS EN 12697-22 is 26 load cycles per 60 seconds. This was the frequency of the apparatus specified in BS 598.

4.1.6 *Carriage and frame* carrying marks to ensure the specimen is at the mid-point of its traverse. Vertical movement at opposite corners of the carriage shall be less than 0.25mm.

4.1.7 *Means for temperature control*, such that the temperature of the sample during testing is uniform and maintained constant at the selected test temperature $45^{\circ}\text{C} \pm 1^{\circ}\text{C}$ or $35^{\circ}\text{C} \pm 1^{\circ}\text{C}$.

4.2 *Tyre pressure gauge* (accuracy to $\pm 0.1\text{bar}$).

4.3 *A means of inflating tyres*.

4.4 *Tyre tread gauge* (accuracy to $\pm 0.1\text{mm}$).

4.5 *Talc, French chalk or limestone filler*.

4.6 *Rubber squeegee / wiper*.

4.7 *Thermometer and/or thermocouples*, of appropriate range, which are capable of measuring to an accuracy of $\pm 0.5^{\circ}\text{C}$, for determining the temperature of the test specimen during conditioning and testing.

4.8 *Sealing compound, mastic or heat-transfer silicone*.

4.9 *Drill, with a masonry bit suitable for drilling small holes in asphalt specimens*.

5 Procedure

5.1 Slab manufacturing

Manufacture three 305mm x 305mm x 50mm asphalt slabs in accordance with Procedure A and apply the HFS to the specimens in accordance with Procedure B. Slab tolerances are indicated in Procedure A.

Condition the specimens to a temperature of $20^{\circ}\text{C} \pm 2^{\circ}\text{C}$.

5.2 Testing before scuffing

5.2.1 *Take photographs* of the surface of the specimen before and after scuffing.

5.2.2 *Mark the centre* of two opposite vertical sides of the slab to indicate the centre of the scuffing track and to allow alignment of the erosion index grid after scuffing

5.2.3 *Measure the surface macrotexture* of the specimen with the HFS prior to tracking in accordance with BS EN 13036-1: 2010 Road and airfield surface characteristics - Test methods Part 1: Measurement of pavement surface macrotexture depth using a volumetric patch technique and Procedure C. The texture depth of the specimen before tracking shall be as declared for the product.

5.2.4 Temperature monitoring hole

Through the test surface of the slab, drill one hole of diameter adequate to hold a thermometer or thermocouple, at 30 mm to 40 mm from the edge of the slab, to a depth of half the thickness.

5.2.5 Conditioning the specimens

Condition the specimens at the specified test temperature for a period of 4 to 6 hours prior to testing.

Note 6: The temperature can be monitored using a dummy specimen or the required temperature conditioning time can be evaluated during pre-calibration tests.

5.3 Performing scuffing test

5.3.1 *Check the tyre* inflation and the tyre tread depth and inspect the tyre for wear or damage.

5.3.2 Insert a thermometer or thermocouple into the temperature monitoring hole so that the tip is at mid depth of the slab, and seal the hole using a suitable mastic compound or a silicone heat-transfer compound

5.3.3 In order to reduce stickiness, it is recommended that an excess talcum powder is applied on the top surface of the specimen. Using a rubber squeegee / wiper, strike off the talcum powder excess, revealing the peaks of the specimen's macrotexture. The talc shall be dry and at the test temperature.

5.3.4 Place one specimen in the scuffing machine and maintain the specified test temperature throughout the testing regime. Secure the specimen rigidly to the table of the machine. Set the centre of the specimen within 10mm of the centre point of the loaded area at the mid-point of transverse. Ensure that the centreline of the slab as marked on the slab coincides with the centreline of the wheel contact patch and that the loaded cantilever arm is horizontal. Set the machine in motion for 500 wheel-passes (250 cycles taking approximately 12 minutes).

5.3.5 Throughout the test, maintain the test specimen at the specified test temperature $\pm 1.0^{\circ}\text{C}$, as measured by the thermometer or thermocouple.

Note 7: It is recommended that the temperature be monitored at intervals of 1 min or less during the test alternatively the temperature may be measured continuously and the maximum and minimum temperatures recorded.

5.3.6 Repeat the steps above for the other two replicate specimens.

5.3.7 Thoroughly wash the specimens to remove residual talc and deposited rubber. Dry the specimens thoroughly at a temperature not exceeding 30°C .

5.3.8 Determine Erosion Index and carry out a visual observation of the specimens after the scuffing test, and record number of squares exhibiting less than 10% material loss in accordance with Procedure D

6 Reporting of results

The test report shall include the following information:

6.1 *Date, time and place of test*

6.2 *Details of the asphalt slab manufacture, including:*

6.2.1 Date and place of manufacture

6.2.2 Material type and specification

6.2.3 Mixing and compaction temperature

6.3 *Details of the high friction surfacing, including:*

- 6.3.1 Date and place of installation
- 6.3.2 HFS name
- 6.3.3 Binder and aggregate type
- 6.3.4 Any installation details (rate of spread of binder, scratch coat, primer, etc.
- 6.3.5 Ambient temperature during installation
- 6.3.6 Mean thickness of the coating of each sample

6.4 *Test data, including:*

- 6.4.1 The mean test temperature of each specimen
- 6.4.2 Initial and final tyre pressures and tread depths
- 6.4.3 Macrotexture of the asphalt slab and initial HFS macrotexture
- 6.4.4 Erosion Index and visual observations, including individual square gradings.
- 6.4.5 Photographs
- 6.4.6 Any anomalies

Procedure A – Requirements for Asphalt Slabs

A.1. General

This section describes the requirements for asphalt slabs for subsequent testing with HFS applied.

A.2. Composition

The slabs shall be asphalt consisting of Stone Mastic Asphalt (SMA) recipe as follows:

BS Sieve Size (mm)

14	100
10	85-100
6.3	22-38
2.0	18-32
0.063	8-12

Binder Grade 40/60

Binder Content 6.3% – 7.3%

Cellulose Fibre 0.30%

A.3. Manufacture and Compaction

Slab manufacture shall be carried out in accordance with BS EN 12697-33.

Each slab shall receive sufficient compaction to ensure that it is adequately robust not to be damaged by subsequent handling. Once fully compacted, the slabs shall be 305mm ± 2mm by 305mm ± 2mm in plan by 50mm ± 10mm thickness.

The upper surface, after compaction, shall have a texture depth measured in accordance with BS EN 13036-1:2010 of 1.05mm ± 0.1mm.

Note 1: Control of macrotexture is required to achieve consistency of HFS binder coverage.

The slabs, when tested in accordance with BS EN 12697-22, shall have a wheel tracking rate of no more than 2.0mm/hr at 45°C.

Note 2: Controlling wheel tracking rate is more important than controlling maximum air voids. Deformation of the slab during the scuffing test may result in cracking of the HFS.

For asphalt manufactured in the laboratory an ageing protocol is necessary to simulate a period of ageing. The slabs in their moulds shall be aged in a ventilated oven at 85°C for a period of 48 hours ± 1 hour.

For asphalt manufactured in an asphalt plant and re-heated prior to slab manufacture the ageing protocol is not required.

Note 3: The volatiles are substantially removed during asphalt plant manufacture and some oxidation of the binder occurs. Oven ageing of laboratory mixed asphalt is used to replicate these changes in order to ensure consistency of adhesion of the HFS binder.

A.4. Storage and transportation

The slabs shall be stored and transported flat so that the whole of the bottom surface is supported at all times, at a temperature of $15^{\circ}\text{C} \pm 10^{\circ}\text{C}$.

During transportation the maximum temperature may be exceeded for short periods.

Slabs shall not be stacked at any time.

Procedure B – Applying High Friction Surfacing and Measurement of the Surfacing Thickness

B.1. General

This section describes the procedure for applying HFS to asphalt slabs for subsequent testing and for measuring the thickness of the surface.

High friction surfaces are applied to slabs by broadcasting high PSV aggregate (usually calcined bauxite 1-3mm granular clean chippings) in excess over a pre-applied binder film.

Note 1 The method usually employed on site should be adopted for the application of HFS. If a scratch coat or other texture filler is used or primer applied then they should be used for the test.

B.2. Apparatus

- *Callipers* – or other suitable apparatus for measuring the dimensions of the specimen to at least ± 0.1 mm between flat discs of 10mm diameter.
- *Specialist Installation Equipment* – as required for the specific system being applied.
- *Containers* –
- *Spatulas* – or other instruments for mixing
- *Toothed combs or squeegees* - for spreading
- *Thermometer* – capable of measuring surface temperatures between -20°C to $+50^{\circ}\text{C}$ to $\pm 1.0^{\circ}\text{C}$.

B.3. Manufacture

Ensure that the required slabs, which comply with Procedure A, are dry and at a temperature of $20^{\circ}\text{C} \pm 10^{\circ}\text{C}$.

Measure the thickness of each slab to ± 0.1 mm at approximately the third-points along each side, at least 30mm in from the edge using the callipers. Mark the points on the bottom face of the slab.

B.4. Applying the HFS

Wire brush the slabs to ensure they have a clean, dry and sound surface, free of any loose particles which can cause lack of adhesion.

Record the temperature of the slab and the ambient temperature prior to coating.

Apply the HFS as specified by the manufacturer's method statement. Ensure sufficient excess aggregate is applied to surcharge the binder to promote wetting out the aggregate.

Allow the HFS to cure in accordance with manufacturer's instructions. Remove any excess and loosely held aggregate from the surface by brushing with a hard bristled broom.

Check the specimens for adequate and uniform coverage, surface defects and slab damage.

Repeat the thickness measurements at the same locations as those used to determine the uncoated slab thickness. Determine the thickness of coating to 0.1mm

B.5. Storage

Cure the coated samples at a temperature of $20^{\circ}\text{C} \pm 5^{\circ}\text{C}$ for 10 days prior testing, ensuring that the whole of the bottom surface is fully supported.

Procedure C – Determination of Macrotexture

C.1. General

This section describes the method of test for determining the volumetric patch texture depth of the asphalt slab and HFS prior to Scuffing Test.

C.2. Apparatus

The apparatus shall be in accordance with Clause 4 of BS EN 13036-1: 2010. The measuring cylinder shall be of 25mL ± 1mL total capacity.

C.3. Procedure

Carry out texture depth measurements under laboratory conditions (on the asphalt slabs) in accordance with BS EN 13036-1: 2010.

C.4. Calculation

Calculate the texture depth of the asphalt slab and HFS specimen in accordance with Clause 6 of BS EN 13036-1: 2010.

C.5. Reporting of Results

The texture depth shall be reported to the nearest 0.1mm.

Procedure D - Test procedure for determination of the Degree of Erosion and Visual Observations

D.1. General

This Appendix describes the method of test for determining the visual condition of a specimen (HFS treated asphalt slab) and the extent of erosion (i.e. aggregate / material loss) that has occurred as quantified by an Erosion Index (EI).

A photograph of the surface of the specimen is taken for record purposes. The EI is measured as the sum of values assigned to 50mm x 50mm squares in a 2 x 5 grid, the individual weighting factor values between 0 and 3 depending on the proportion of material eroded in that square to expose the asphalt slab. Hence, the erosion index can have a value between 0 (less than 25% erosion) and 30 (at least 75% eroded). The surface of the specimen is surveyed for any abnormalities.

D.2. Apparatus

The apparatus shall consist of:

- *Digital camera of minimum resolution of 8 megapixels*
- *Grid (rigid mesh), not less than 100mm wide by 250mm long divided into 50mm x 50mm grid squares (tolerance on dimensions ± 0.5 mm).*

D.3. Record Photograph

Place the grid over the centre of the specimen with the centre bar of the grid in line with the centreline marks applied before testing and the longer side parallel to the wheel path and the grid over the tracked area. Place a label adjacent to the specimen giving the specimen reference number, the test regime being carried out and the number of wheel-passes completed.

Take photographs of the specimen before and after scuffing test. For the latter, the full frame of the picture shall contain the grid.

D.4. Erosion Index

Place the grid over the centre of the specimen with the longer side parallel to the wheel path and the grid over the tracked area, as shown in **Figure D.1**.

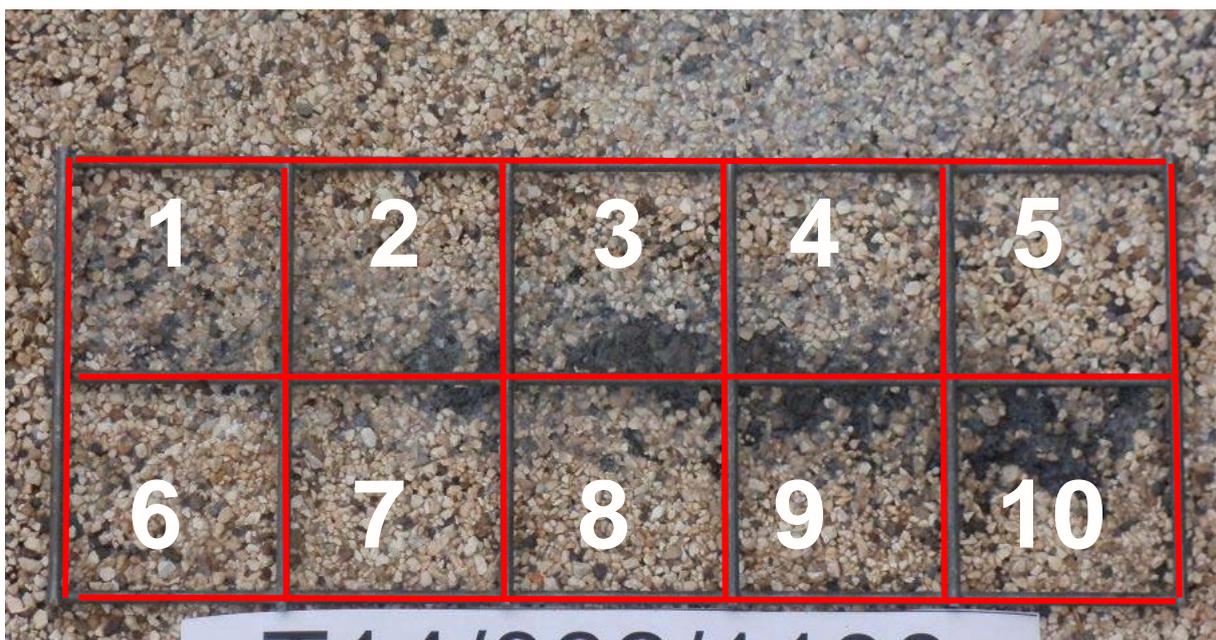


Figure D.1 Typical Grid Placement

Assess the degree of erosion of each of the 10 grid squares according to the ratings as defined in **Table D.1** and record the number of squares in each grade.

Grade	Area of Coating (including aggregate) Remaining	Weighting Factor
a	Greater than or equal to 90%	x 0
b	Greater than or equal to 75% and less than 90%	x 0
c	Greater than or equal to 50% and less than 75%	x 1
d	Greater than or equal to 25% and less than 50%	x 2
e	Less than 25%	x 3

Table D.1 Assessment of Rating of Grid Squares

For example from **Figure D.1** “grade a” may be visually established for grids 1, 2, 4, 5, 6, 7 and 8; “grade b” established for grid 9; “grade c” established for grids 3 and 10.

Calculate the EI by multiplying the number of squares in each grade by the respective weighting factor given in **Table D.2** for that grade and add together the four sub-totals to give the EI value. The EI shall be reported as illustrated in the example from **Figure D.1** shown in **Table D.2** below.

Grade	Number of Squares	Weighting Factor	Erosion Index
a	7	x 0	0
b	1	x 0	0
c	2	x 1	2
d	0	x 2	0
e	0	x 3	0
Total: 10			Total: 2

Table D.2 Erosion Index Report

Note: The erosion index will be 0 for a specimen on which the HFS is still completely intact and 30 for a specimen on which at least 75% has been visually assessed as being completely removed.

The EI measurement presented above shall be assessed and reported by 2 separate observers and the mean shall be reported. If “grade a” scores are found in all grid squares, this material may be reported as a premium product.

D.5. Visual Observation

Standing with a light source behind the observer, view the specimen with each of the four sides nearest to the observer in turn. Note the presence of any faults or abnormalities other than loss of coverage by the high friction surface over parts of the specimen, as measured by the EI. Possible faults include:

- uniform loss of, or loose, aggregate (and hence a reduction in the spread of the aggregate that remains);
- cracking of the surface and/or the substrate; and
- delamination of areas of the surface from the substrate.

Repeat the above with the light source beyond the specimen. Record any faults observed.