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Performance Specified Surface Dressing for Trunk Roads

Sub-task 3
Desk Study of Scuffing Test Methods

Report

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1. Introduction

1.1 Purpose of Document

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

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

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

This report presents the findings from Sub-Task 3.

1.2 Background

It is understood that the Highways Agency (HA) and the British Board of Agrément (BBA) have some concerns over the recently reported high variations in "wear test" results during the certification process of HFS systems, carried out by two laboratories. However, there was not enough clarity with regard to the "wear test" in question. In addition to this, it is understood that the main concern about the variability of the test results was primarily related to testing Thermoplastic HFS Type 1.

Currently there are two known published "wear test" methods for testing HFS, specifically:

- TRL Report 176 (Nicholls, 1997);
- BBA HAPAS "Guideline document for the assessment and certification of high-friction surfacing for highways", RSG1.08.189 (BBA, 2008).

The above documents make reference to two types of "wear test", namely: Scuffing and Wear. During the early discussion with the HA, Arup URS Consortium was requested to investigate which one of these types of tests was reported to have issues with high variations in test results.

Wear Test

The Wear Test is cited in Appendix H of TRL report 176 (Nicholls, 1997) and Appendix D.8 of BBA HAPAS (BBA, 2008).

It is understood that, to date, there is only one laboratory that is able to perform the Wear Test, using equipment called the Road Test Machine (RTM), Figure 1. The civil engineering laboratory at the University of Ulster has been using this equipment to carry out third party assessments on the Wear Test, on the behalf of BBA under the HAPAS SG3 scheme. Hence, only a single item of equipment from a single laboratory is involved in this test. In this context, therefore, it can be concluded that the current HA/BBA concerns are not related to results from the RTM Wear Test.

Figure 1: Road Test Machine

Scuffing Test

The Scuffing Test is cited in Appendix G of TRL report 176 (Nicholls, 1997) and Appendix D.7 of BBA HAPAS (BBA, 2008). This test is normally followed by determination of Erosion Index in accordance with Appendix F and Appendix D.6 of these documents, respectively.

Previously, Thameside Test & Research Limited (TTRL) was the only laboratory approved to carry out the Scuffing Test on the behalf of BBA. However another laboratory, PTS, has subsequently obtained accreditation to perform the Scuffing Test. Following direct contacts and meetings with TTRL and PTS, it was concluded that HA/BBA concerns were related to the variability of the Scuffing Test results performed by these two laboratories. Consequently, this report is exclusively focused upon assessing the variability of the Scuffing Test.

2. Methodology

Considering the time and financial constraints, it was agreed with the HA Client Package Order Manager that the assessment would be carried out by a desk study, comprising:

- Review of Scuffing Test and the associated assessment methods;
- Review of available information associated with variability of the test methods;
- Meetings and discussions with the two laboratories accredited to carry out the Scuffing Test (TTRL and PTS);
- Summary of findings and recommendations.

3. Review of Scuffing Test Methods

BBA HAPAS document RSG1.08.189 (BBA, 2008) basically follows the methods for testing in accordance with the Appendices of TRL Report 176, but with some amendments. The details are contained in Appendix D of the BBA HAPAS document; these are reproduced in Appendix 1. For completeness, Appendices F and G of TRL Report 176 are reproduced in Appendix 2.

The Scuffing Test carried out to the BBA HAPAS suite of testing broadly involves:

- Laboratory manufacturing of SMA substrate with certain performance characteristics, specifically wheel tracking rate of not greater than 2mm/h at 45ºC with a texture depth of 1.05 ± 0.1mm;
- Application of HFS over the laboratory manufactured SMA substrate;
- Testing of two different sample conditions i.e. unaged and post-ageing;
- Testing at two different test temperatures i.e. either 35ºC or 45ºC, dependent upon the performance criteria and classification of HFS (i.e. Type 1, 2 or 3);
- Scuffing Test on a set of 3 specimens;
- Texture depth measurements on specimens before and after the Scuffing Test;
- Erosion Index (EI) determination after the Scuffing Test, using visual assessment and a standard grid scale of not less than 100mm wide by 250mm long, divided into 50mm x 50mm squares by a steel mesh.

Skid Resistance Value (SRV) assessment by British Skid Pendulum is normally carried out before the Scuffing Test.

Considering the above, there are a number of factors which may affect the repeatability and reproducibility of the test method, including:

- Variations in the SMA substrate, due to potentially different material composition, volumetrics, sample manufacturing procedures and possible effect of scuffing test temperature (35ºC or 45ºC). Whilst the absolute texture value may be considered to realistically simulate site appearance, the specified texture depth for the SMA substrate is very restrictive (the permitted tolerance is smaller than the precision of the volumetric patch test method) and therefore may be difficult to achieve; in this case, replacing the texture depth requirement with a small range of permitted air voids (e.g. between 2% and 4%) could be a better way forward.
- Variations in the ‘family’ of HFS, i.e. cold or hot applied HFS, are known to have different curing and performance characteristics. The effect of temperature variations on the properties of cold applied HFS systems is marginal since these materials are predominantly thermosetting in nature, whilst hot applied HFS systems are greatly affected by temperature changes (i.e. being thermoplastic material).
- Variations in scuffing machines, including condition of test apparatus and its components (e.g. tyre wear and size, tread pattern, inflation pressure).
- Subjective assessments by different operators and/or laboratories, more importantly during visual assessments such as determination of EI.

- Variability in the texture depth measurements, and the questionable accuracy of the test method on a relatively small surface area.
- The current test method is not prescriptive enough and the test requirements are not contained within a single standard. Currently, the BBA HAPAS (2008) document makes reference to TRL Report 176 Appendix G with a few amendments noted in the current document. This is open to varied interpretation.

The above list is not exhaustive but suggests complex interrelated variables may contribute to variability of test results.

4. Meetings and Discussions with TTRL and PTS Laboratories

4.1 Meeting with TTRL

On 19 June 2013, a meeting between Daru Widyatmoko (URS), Martin Heslop (Acland) and Paul Shrubsole (TTRL) was held at TTRL laboratory in Meopham, Kent.

During the visit, Mr Shrubsole explained the procedures adopted for the Scuffing Test and demonstrated how the associated visual assessment was carried out. According to Mr Shrubsole, TTRL and PTS laboratories have carried out some comparative scuffing tests; however, the results and interpretation of test results varied significantly.

Key findings from this visit:

- Tyre tread: TRL Report 176 specifies a minimum depth of 1.0mm. TTRL typically used tread depth of not less than 1.4mm. Eventually, the depth of the tyre read will reduce after being filled by debris from the scuffed surface. In this situation, the tyre must either be cleaned (to restore the tread depth) or replaced by a clean tyre. It is possible to rotate the same tyre in order to obtain a clean tread. It was found that thermoplastic systems filled the tread more quickly than resin based systems.
- Tyre size: TTRL has been using a different pneumatic tyre size (215mm ± 2.5mm diameter) which is larger than that specified in TRL Report 176 (any size from 200mm to 205mm diameter is permitted); the smaller tyre size was reported to result in less damage. It is understood that the 215mm diameter tyre size was supplied by Bickle Castors and Wheels Limited of Milton Keynes, and has been adopted by the BBA since (at least) 2005.
- Use of talcum powder: in order to reduce stickiness, TTRL has normally used a moderate to heavy application of talcum powder on the tracked surface. Whilst this practice is actually contrary to that recommended in sub-clause G.5.6 of TRL Report 176 Appendix G, TTRL found it necessary to use generous applications of talcum powder.
- EI: The EI value is determined using a standard grid scale in accordance with TRL Report 176 Appendix F, to determine the area which remains coated with HFS after being subjected to the Scuffing Test. In this context, the BBA HAPAS document has added further definitions:
    - "The loss of binder and/or aggregate shall constitute erosion";

- "For thermoplastic systems only any area of melting or displacement shall be regarded as being erosion".

TTRL laboratory reported EI as an average value of two independent visual assessments by two different operators. However:

- This visual assessment is very subjective, open to interpretation, and uses a standard grid scale against a rating method as detailed in TRL Report 176 Appendix F, as shown in Table F.1 and Figure F.1 (reproduced in Appendix 2 of this report). Occasionally, two operators had to repeat the assessment when there was a large difference in the rating given by each assessor; repeat assessments would normally take place on the following day.
- It is difficult to assess the EI for deformable materials (such as thermoplastic systems) because after the Scuffing Test, failures may be manifested as material loss (hence 'erosion') on some grid squares but gain (hence 'swelling') on some other grid squares. This makes the rating assessments of the grid squares even more subjective.

TTRL scuffing test equipment and its accessories are presented in Figure 2.

TTRL Scuffing Test Equipment

215mm Diameter Tyres

Grid Scale for EI Assessment

Figure 2: Scuffing Test Equipment - TTRL

In addition to the above, URS was provided with two sets of documents presenting research work carried out by TTRL, investigating an alternative to the Scuffing Test for surveillance testing of thermoplastic HFS systems. The content of these documents will be discussed in a later section of this report.

4.2 Meeting with PTS

On 26 June 2013, Daru Widyatmoko (URS) visited PTS laboratory in Adlington, for a meeting with David O'Farrell, Tony Sewell and Anthony Collier (PTS).

During the visit, Mr O'Farrell explained about their work on the Scuffing Test and Mr Collier demonstrated how the test was setup and the visual assessment associated with the testing was carried out. PTS has modified the British Standard small scale wheeltracker for the Scuffing Test; the setup is illustrated in Figure 3.

Figure 3: PTS Scuffing Test Equipment

During the visit, URS was provided with the following PTS reports:

- PTS1219-X- BBA - Thameside - PTS - Scuffing Approval Hitex Dark Chinese TYPE 1 Edge Lane Liverpool, Set 1 Thameside Scuffing Test Report 030412 Issue 2.
- PTS1219-X- BBA - Thameside - PTS - Scuffing Approval Hitex Dark Chinese TYPE 1 Edge Lane Liverpool, Set 2 Scuffing Test Report 230312.
- PTS1219-X- BBA - Thameside - PTS Scuffing Approval Hitex Dark Chinese TYPE 1 Edge Lane Liverpool, Set 3 Thameside Scuffing Test Report 030412 Issue 2.
- PTS1219-X- BBA - Thameside - PTS Scuffing Approval Hitex Dark Chinese TYPE 1 Edge Lane Liverpool, Set 4 Scuffing Test Report 230312.

The above reports present work which PTS completed as part of comparative scuffing tests with TTRL. Unfortunately, the reports exclusively contained PTS test results only and therefore do not demonstrate how much difference there was between the PTS results and those of TTRL. However, based upon the available details and the discussion with PTS, specifically on the test setup, it was revealed that:

- PTS was using the 200mm diameter pneumatic tyre (complying with TRL Report 176) which was smaller than that used by TTRL (215mm, complying with the BBA HAPAS document);
- In order to reduce stickiness, PTS used a light application of talcum powder (as recommended in TRL Report 176), whilst TTRL has applied more generous amounts of powder on to the tracked surface.

- PTS carried out the EI determination based on a single operator assessment, whilst TTRL used an average value from two independent operators. The former approach was in compliance with TRL Report 176, whilst the latter was merely a voluntary decision intended to improve confidence in the visual assessments.

5. General Discussion

Based upon limited information and discussion with the two accredited laboratories (PTS and TTRL), it appears that the test setup and interpretation plays a significant role in the variability of the reported test results.

There has been an initiative to carry out a comparative study between PTS and TTRL; this study also involved BBA. However, there was a large variation reported from the test results. Whilst full details have not been made available to URS, these variations could be due to a number of reasons:

- Tyre size: PTS used the smaller tyre size as specified in TRL 176 (i.e. 200mm diameter) during the comparative study with TTRL.
  - As noted during the visit, however, PTS has started using the 215mm diameter tyre, obtained from the same tyre supplier as that used by TTRL.
  - Whilst the full report from this study is not available to URS, the difference in tyre sizes is believed to be the main reason for the large variability in the Scuffing Test results between these two laboratories.
  - The logical next step would have been to repeat the study (since both laboratories now use the same tyre); however, this has not been done due for financial reasons. PTS was requested to fund the second study but declined.
- Currently there are no data to substantiate the effect of talcum powder application on the scuffing resistance of HFS. However, the application rate of talcum powder should be standardised to avoid possible effects on the test results.
- For thermoplastic systems, there appears to be inconsistency in determining the area under the grid squares. It may be difficult to agree how to rate the erosion level for an area where thermoplastic surfacing has melted or displaced after the Scuffing Test. Discussions with various parties involved with the test suggest that the current procedure is not suitable for thermoplastic systems.
- EI: TRL Report 176 allows the visual assessment to be carried out by a single operator; however, it does not explicitly prohibit having multiple independent assessments. Therefore, clarity is required to ensure consistency between test results. In this context, it is recommended that a mean of 3 independent assessments should be adopted.

The above appears to have been exacerbated by the lack of clarity in the adopted test procedures, which are open to different interpretation regarding how a test or assessment must be performed. Cross-referencing between the two separate documents, i.e. TRL Report 176 and BBA HAPAS guidelines, may also contribute to the loss of clarity due to discontinuity of information.

Following on from the above, it is essential that the test procedures should be revised and improved for clarity, and that these should be contained within a single document to ensure continuity of information.

Considering the mode of failure, specifically for thermoplastic systems (which leads to complication during the assessment of EI) an alternative assessment method is warranted.

6. Other Useful Documents

During the visit to TTRL laboratory, URS was provided with the following documents:

- "An investigation into the scuffing test as applied to thermoplastic HFS systems" (TTRL1);
- "Investigation into an alternative to the scuffing test for surveillance testing of thermoplastic HFS systems" (TTRL2).

Reviewing an alternative to the Scuffing Test method is not part of the current Task 136(4/45/12)ARPS. For completeness, however, key findings from the above documents are summarised here:

- "Thermoplastic binders seldom, if ever, fail under test by the erosion of the coating. The mode of failure is softening and displacement of the HFS coating by the elevated test temperature and the action of the scuffing tyre" (TTRL1).
- There was a change in appearance observed on a thermoplastic system with zero EI, where aggregate had been embedded into the binder and the scuffing track had a smoother surface, resulting into a drop in macrotexture of 25-35%. This phenomenon is different to that observed on the road, where reduction in macrotexture is less likely. (TTRL1)
- Pigmented thermoplastic systems have given higher EI than those of black versions. (TTRL1)
- TTRL has hypothesised that there could be a critical temperature, which occurs just a few degrees below the standard 45˚C, beyond which the EI value increases dramatically. (TTRL1)
- TTRL also suggested that an alternative test is required and it should be: discriminatory; repeatable and reproducible; performed on the melted material taken from the boiler on site; of sufficient mass to negate variations within the mixture and investigate the thermo-mechanical properties of the mixture, and; ideally, able to be performed by manufacturers to aid in development and quality control. (TTRL1, TTRL2)
- Two thermo-mechanical tests were reported: an indentation test (adapted from BS EN 1871) and a bespoke creep stiffness test. However the results did not correlate with the Scuffing Test EI; therefore, further investigation into an alternative test method is warranted. (TTRL2)

The above findings suggest the following:

- Scuffing is not appropriate for testing thermoplastic HFS systems, due to differences in the shear (scuffing) resistance phenomenon observed in the laboratory and on site.
- An alternative method to assess scuffing resistance of thermoplastic HFS systems is required and this requires further investigation.

In addition to the above, during the visit to PTS, URS was also provided with a report produced by Cumbria County Council on the performance of HFS in Cumbria. This report contains a substantial database of in service performance of various types of HFS, which may be used as a good reference point when reviewing the current specification adopted for HFS. As with investigating an alternative to the Scuffing Test, a review of the HFS specification is not a part of the current Task 136(4/45/12)ARPS and therefore is not discussed further in this report.

7. Conclusions and Recommendation

7.1 Conclusions

This desk study reported the findings from a review of the Scuffing Test method and possible reasons for the observed variability of test results reported by TTRL and PTS laboratories during their comparative study.

The main reasons appear to be related to inconsistent testing equipment (e.g. different tyre sizes) and approach adopted to analyse test results (e.g. single/multiple visual assessment and the amount of talcum powder used during testing).

In addition to the above, the current setup for the Scuffing Test is not considered to be suitable to assess the performance of thermoplastic HFS systems.

7.2 Recommendations

Considering the above conclusions, the following further works are recommended.

Due to the different nature of HFS systems and limitations of the current Scuffing Test method, it may be necessary to apply different test methods for different systems.

- 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, as presented in Section 3 of this report.
- 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 mixture, investigate the thermo-mechanical properties of the mixture and, ideally, able to be performed by manufacturers to aid in development and quality control. This future work should involve distinctively defining erosion

or “wear” under scuffing test and validating the test results against the performance of thermoplastic systems in situ.

The BBA HAPAS specification (2008) would need to be updated to account for any findings from carrying out the above recommendations.

8. References

BBA HAPAS (2008), “Guideline document for the assessment and certification of high-friction surfacing for highways”, RSG1.08.189, March.

Cumbria County Council (2012), “Report on the performance of High Friction Surfacing in Cumbria”, Volume 1 – Report and Appendices, January.

Nicholls, J.C. (1997), “Laboratory tests on high-friction surfaces for highways”, TRL Report 176, Crowthorne. ISSN 0968-4107.

Thameside Test & Research Limited (TTRL1), “An investigation into the scuffing test as applied to thermoplastic HFS systems”.

Thameside Test & Research Limited (TTRL2), “Investigation into an alternative to the scuffing test for surveillance testing of thermoplastic HFS systems”.

APPENDICES

APPENDIX 1 – Laboratory Test Methods and Procedures

Reproduced from Appendix D of BBA HAPAS document RSG1.08.189 (March 2008)

APPENDIX D

Laboratory test methods and procedures

For the purpose of the assessment of High-Friction Surfacing the following test methods and procedures have been agreed by the Specialist Group 1 – High-Friction Surfacing.

1. Requirements for SMA slabs are given in Appendix E

2. Requirements for concrete slabs are given in TRL Report 176 (1977): Appendix B with the following amendments:

Clause B.4.3 Delete '*either*' and '*or (150 ±2) mm*' by '*(150 ±2) mm*'

3. Procedure for applying High-Friction surfaces and the measurement of the surface thickness are given in TRL Report 176 (1977) : Appendix C with the following amendments:

Clause C.4.1 Delete '*±0.1mm*' and replace with '*±0.25 mm*'

Clause C.4.1 Delete '*discs of (10 ±1) mm diameter*' and replace with '*discs of between 10 mm and 20 mm diameter*'

Clause C.4.7 Delete '*±1.0C* and replace with '*±2.0°C*'

Clause C.5 The 20 mm perimeter of the test slab surface shall not form part of the test area.

Clause C.5.2.2 Delete '*±1.0°C*' and replace with '*±2.0°C*'

Clause C.5.3.2 Delete '*±0.2 mm*' and replace with '*±0.5 mm*'

Clause C.5.4 The clause shall be amended to read:

Cure the coated samples at a temperature of (20 +/-5)°C for 7 days prior to testing. If the samples are not ready for testing after the 7 days, cure period they shall be stored flat so that the whole of the bottom surface is supported at a temperature of (5 +/-2)°C.

4 Procedure for determination of texture depth is given in TRL Report 176 (1977) : Appendix D with the following amendment:

The use of any steel rule, conforming to BS 4372 of 300 mm or more in length, shall be allowed.

5. Procedure for the determination of skid resistance value is given in TRL Report 1796 (1977) : Appendix E.

6. Test procedure for determination of the degree of erosion and visual observations are given in TRL Report 176 (1977) : Appendix F with the following amendments:

Clause F.7.1 Visual observations to be carried out under daylight only.

Table F.1 Delete '*Area of Coating Remaining*' and replace with '*Area of coating (including aggregate) remaining*'.

Clause F.6.2 '*For thermoplastic systems only any area of melting or displacement shall be regarded as being erosion*'.

'*The loss of binder and/or aggregate shall constitute erosion*'

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7. **Test procedure for scuffing is given in TRL Report 176 (1997) : Appendix G with the following amendments:**

Clause G.4.2	Delete '*200 mm and 205 mm*' and replace with '*(215.0 ±2.5) mm*' Delete '*(3.1 ±0.1) bar*' and replace with '*(3.1 ±0.2) bar*'
Clause G.4.3	Delete '*(520 ±5) N*' and replace with '*(520 ±20) N*'
Clause G.4.5	Delete '*(21 ±0.2) load cycles*' and replace with '*(21 ±0.5) load cycles*'
Clause G.4.7	Delete '*(45 ±1.0)°C*' and replace with 'either *(35 ±1.0)°C or (45 ± 1.0)°C*. For Type 1 and 2 systems the testing shall be carried out at *(45 ± 1.0)°C* and for type 3 systems at *(35 ± 1.0)°C.*'
Clause G.5.3	Temperature measurement to be surface temperatures in accordance with BS 498 : Part 110.
Clause G.5.6	Delete '*ambient temperature at (45 ±1.0)°C*' and replace with '*test temperature of (45 ±1.0)°C* or *(35 ±1.0)°C*'.
Clause G.5.9	Temperature measurement to be surface temperatures in accordance with BS 598 : Part 110.

8. **Test procedure for wear is given in TRL Report 176 (1977) : Appendix H with the following amendments:**

Clause H.4.7	Delete '*±1.0°C*' and replace with '*±2.0°C*'.
Clause H.5.1	Delete '*(2.0 ±0.1) bar*' and replace with '*(2.0 ±0.2) bar*'.
Clause H.5.3	Delete '*(10 ±2)°C*' and replace with '*(20 ±2)°C*'.
Clause H.5.4	Add the following text at the beginning of the clause: '*Condition the samples in an environment maintained at (10 ±2)°C for a period of greater than 4 hours*'.
Clause H.5.5	Delete '*When the surface temperature is in the range (10 ±2)°C,*' and replace with '*Condition the samples in an environment maintained at (20 ±2)°C and when the surface temperature is in the range of (20 ±2)°C.*'

9. **Test procedure for tensile adhesion is given in TRL Report 176 (1977) : Appendix J with the following amendments:**

Clause J.4.1	Load cell to be Grade 2 accuracy to BS 1610 and of a suitable capacity.
Clause J4.4	Note: An angle grinder fitted with a diamond blade has been found suitable for cutting through the high-friction surfacing.

10. **Procedure for heat-ageing conditioning is given in TRL Report 176 (1977) : Appendix K with the following amendments:**

Clause K.4.1	Delete '*complying with BS 2648.*'. Oven must be capable of maintaining the sample temperature at (70 ±3)°C.
Clause K.5.3	Sample edges must be supported during heat ageing. A minimum conditioning period of 24 hrs at (5 ±2)°C shall be allowed prior to scuffing.

11. Procedure for freeze/thaw conditioning is given in TRL Report 176 (1977) : Appendix L with the following amendments:

Clause L.3 Note: The temperatures relate to the conditioning chamber

Clause L.5.3 A metal frame (sealed using a suitable sealant) is to be used to retain the brine solution instead of road tape.

Brine solution to be made using sodium chloride (GP grade).

Clause L.5.7 Delete *'a single specimen'* and replace with *'two samples'*

12. Procedure for diesel susceptibility conditioning is given in TRL Report 176 (1977) : Appendix M with the following amendments:

Clause M.5.3 Metal frame (sealed using a suitable sealant) to be used to retain the diesel oil instead of road tape.

Clause M.5.5 Samples to be stored in a temperature controlled environment at (5 ±2)°C prior to testing.

Clause M.5.7 Delete *'a single specimen'* and replace with *'two samples.'*

13. Test procedure for determination of thermal movement is given in TRL Report 176 (1977) : Appendix N with the following amendments:

Clause N.5.6 Note: Temperature measurements to be surface temperatures.

Clause N.5.7 Note: Temperature measurements to be surface temperatures.

Clause N.5.8 Three samples to be tested, once each.

14. Test procedures for optional tests are given in TRL Report 175 (1977) : Appendix P with the following amendments:

Table P.1 Delete *'Extreme claimed ±2°C'* and add the following:
Minimum claimed installation temperature +0°C & -2°C
Maximum claimed installation temperature -0°C & +2°C

Clause P3 and Table P1

Test samples for the substrate texture depth and concrete substrate optional tests may be prepared in accordance with Appendix C of TRL Report 176 during the preparation of the test samples for the mandatory tests.

APPENDIX 2 – Procedures for Determination of Erosion Index (EI) and Scuffing Test

Reproduced from Appendices F and G of TRL Report 176.

APPENDIX F: TEST PROCEDURE FOR DETERMINATION OF THE DEGREE OF EROSION AND VISUAL OBSERVATIONS

F.1 SCOPE

This Appendix describes the method of test for determining the visual condition of a specimen, including the extent of erosion that has occurred as quantified by an erosion index.

F.2 DEFINITIONS

For the purposes of this Appendix, the definitions given in BS 598: Part 100 apply.

F.3 SUMMARY OF TEST METHOD

A photograph of the surface of the specimen is taken for record purposes. The erosion index is assessed as the sum of values ascribed to 50mm x 50mm squares in a 2x5 grid, the individual values between 0 and 3 depending on the proportion of material eroded in that square to expose the specimen. Hence, the erosion index can have a value between 0 (no erosion) and 30 (completely eroded). The surface of the specimen is surveyed for any abnormalities.

F.4 APPARATUS

The apparatus shall consist of:

F.4.1 *Camera* with a lens of 50mm focal length taking 35mm film.

F.4.2 *Flash unit.*

F.4.3 *Camera housing* (optional) which will accommodate a 305mm by 305mm specimen plus identifying label at (500±100)mm perpendicularly from the camera whilst excluding light. The flash unit shall be capable of being installed so as to be able to illuminate the specimen at an angle of (45±12)° from the plane of its upper surface.

NOTE. The housing described in Appendix 2 to Road Note 27 is suitable for this purpose.

F.4.4 *Grid*, not less than 100mm wide by 250mm long divided into 50mm x 50mm squares by a steel mesh.

F.5 RECORD PHOTOGRAPH

F.5.1 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. 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.

F.5.2 Position the camera (500±100)mm perpendicularly over the specimen and position the flash unit so as to be able to illuminate the specimen at an angle of (45 ±12)° from the plane of its upper surface, using the camera housing if required. Adjust the focus and aperture size to the relevant settings and take a photograph of the specimen and label with the camera whilst the specimen is illuminated by flash light.

F.5.3 Store the photographic prints and retain for not less than two years.

F.6 EROSION INDEX

F.6.1 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.

F.6.2 Assess the degree of erosion of each of the 10 grid squares according to the ratings as defined in Table F.1 and record the number of squares in each grade.

F.6.3 Calculate the erosion index by multiplying the number of squares in each grade by the respective weighting factor given in Table F.1 for that grade and add together the four sub-totals to give the erosion index.

NOTE. The erosion index will be 0 for a specimen on which the high-friction surface is still completely intact and 30 for a specimen on which the surface has been completely removed.

F.7 VISUAL OBSERVATIONS

F.7.1 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 erosion index. 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
- de-lamination of areas of the surface from the substrate.

F.7.2 Repeat F.7.1 with the light source beyond the specimen.

F.7.3 Record any faults observed.

F.8 PRECISION

The precision of the test method has still to be determined.

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TABLE F.1

Assessment of Rating of Grid Squares

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

NOTE. The tabular form shown in Figure F.1 is recommended.

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

Figure F.1: Specimen Erosion Index Table

F.9 REPORTING OF RESULTS

The test report shall include the erosion index to the nearest unit and any observations made as to the visual condition of the specimen.

F.10 REFERENCES

BRITISH STANDARDS INSTITUTION (1987). Sampling and examination of bituminous mixtures for roads and other paved areas, Part 100. Methods for sampling for analysis. *BS 598: Part 100: 1987*. British Standards Institution, London.

ROAD RESEARCH LABORATORY (1969). Instructions for using the portable skid-resistance tester. *Department of Scientific and Industrial Research, Road Note No.27.* Her Majesty's Stationery Office, London.

APPENDIX G: TEST PROCEDURE FOR SCUFFING

G.1 SCOPE

This Appendix describes the method of test for determining the resistance to wear by scuffing of a high-friction surface at an elevated temperature.

G.2 DEFINITIONS

For the purposes of this Appendix, the definitions given in BS 598: Part 100 apply.

G.3 SUMMARY OF TEST METHOD

A loaded pneumatic-tyred wheel which is set at an angle to the direction of motion is repeatedly passed over the surfacing of a specimen at an elevated ambient temperature. The change in texture depth and erosion index occurring after a set number of passes are used to determine the resistance of a high-friction surface system to wear by scuffing.

G.4 APPARATUS

The apparatus shall consist of:

G.4.1 *Scuffing-wheel apparatus* consisting 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 axis of the wheel held at an angle of (20±1)° to the vertical plane perpendicular to the direction of travel. Vertical play in both the loaded wheel bearings and the lower arm pivot point shall be less than 0.25mm. A typical layout is shown in Figure G.1.

G.4.2 *Pneumatic tyre* of outside diameter between 200mm and 205mm fitted to the wheel. The tyre shall be inflated to (3.1±0.1)bar (45psi) have a ribbed tread of not less than 1mm.

G.4.3 *Weighted cantilever arm*, to apply a load to the wheel under standard test conditions of (520±5)N, measured at the level of the top of the specimen and normal to the plane of the sample table.

G.4.4 *Sample table*, constructed so as to enable a 305mm by 305mm rectangular 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.

G.4.5 *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±5)mm.

NOTE. This form of motion is most readily achieved by a reciprocating drive from a crank but alternative drive mechanisms are satisfactory as long as the motion conforms with the above requirements.

G.4.6 *Carriage and frame carrying moulds* to ensure the specimen is at the mid-point of its traverse (see G.4.5). Vertical movement at opposite corners of the carriage shall be less than 0.25mm.

G.4.7 *Means for temperature control*, such that the temperature of the specimen during testing is uniform and maintained constant at (45±1)°C.

NOTE. A constant temperature room enclosing the machine is one method of meeting this requirement.

G.4.8 *Tyre pressure gauge.*

G.4.9 *Pump* suitable for inflating tyres.

G.4.10 *Tyre tread gauge.*

G.4.11 *Talc, french chalk or limestone filler.*

G.5 PROCEDURE

G.5.1 Measure the angle between the line of motion and the plane of the wheel.

G.5.2 Manufacture three 305mm by 305mm asphalt slabs in accordance with Appendix A and apply the high-friction surface to the specimens in accordance with Appendix C other than when the scuffing test is part of the installation temperature, the substrate texture depth or the concrete substrate tests. For the installation temperature, the substrate texture depth or the concrete substrate tests, manufacture three specimens in accordance with F.5.1 to F.5.5 of Appendix F.

G.5.3 Condition the specimens to a temperature of (20±2)°C. Measure the texture depth in accordance with Appendix D of the specimens prior to tracking.

G.5.4 Condition the specimens in an environment of (45±1)°C for a period of 4 to 6 hours prior to testing.

G.5.5 Check the tyre inflation and the tyre tread depth and inspect the tyre for wear or damage.

G.5.6 Place one specimen in the scuffing machine and maintain throughout the testing regime the ambient temperature at (45±1)°C. Secure the specimen rigidly to the table of the machine. If the surface of the specimen is sticky,

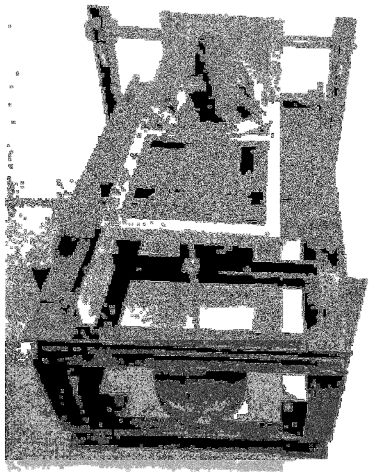

Fig. G1 Suitable scuffing machine

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lightly dust it with talc, french chalk or limestone filler. Set the centre of the specimen within 10mm of the centre point of the loaded area at the mid-point of transverse. Set the machine in motion for 500 wheel-passes (250 cycles taking approximately 12 minutes).

G.5.7 Repeat G.5.5.

G.5.8 Repeat G.5.5 to G.5.7 for the other two replicate specimens.

G.5.9 Condition the specimens to a temperature of (20±2)°C. Measure the texture depth and erosion index, including carrying out a visual observation, in accordance with Appendix D and Appendix F respectively, of the specimens after testing.

G.6 CALCULATIONS

G.6.1 The initial and final texture depths and the final erosion index for the high-friction surface are the mean values from the three determinations.

G.6.2 The loss of texture depth and the loss of skid-resistance value for the high-friction surface are calculated as

$$\text{loss} = 100 \times \frac{(\text{Initial value - Final value})}{\text{Initial value}} \%$$

G.7 PRECISION

The precision of the test method has still to be determined.

G.8 REPORTING OF RESULTS

The test report shall include the following information:

a) date, time and place of test;

b) details of the slabs manufacture including:
- date and place of manufacture;
- the material type and specification;
- the grading and proportion of each aggregate source used;
- the source, type and grade of the binder and any binder modifier;
- the temperature at which the slab was manufactured;
- the texture depth of the substrate; and
- the number of the relevant Appendix, i.e. TRL Report 176, Appendix A or Appendix B;

c) details of the high-friction surface including:
- date and place of installation;
- the high-friction surface system name;
- the binder and aggregate type;
- batch numbers for the binder and aggregate;
- ambient temperature during installation;
- the mean thickness of high-friction surface on each specimen; and
- the number of the Appendix, i.e. TRL Report 176, Appendix C;

d) temperature at which the test was carried out;

e) initial and final tyre inflation pressures and tread depths for the test on each specimen;

f) angle between the line of motion and the plane of the wheel;

g) the initial texture depth of each specimen and the mean value for the high-friction surface system;

h) the final texture depth, erosion index and visual observations of each specimen and the mean values for the high-friction surface system;

i) The loss of texture depth with scuffing for the high-friction surface;

j) the name of the person taking technical responsibility for the test;

k) the number of this Appendix, i.e. TRL Report 176, Appendix G;

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

G.9 REFERENCES

BRITISH STANDARDS INSTITUTION (1987). Sampling and examination of bituminous mixtures for roads and other paved areas, Part 100. Methods for sampling for analysis. *BS 598: Part 100: 1987*. British Standards Institution, London.

APPENDIX H: TEST PROCEDURE FOR WEAR

H.1 SCOPE

This Appendix describes the method of test for determining the resistance to wear by repeated turning wheels of a high-friction surface at a low temperature.

H.2 DEFINITIONS

For the purposes of this Appendix, the definitions given in BS 598: Part 100 apply.

H.3 SUMMARY OF TEST METHOD

A pair of loaded pneumatic-tyred wheels revolve so as to repeatedly pass over the surfacing of a series of specimens