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<tr>
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Remarks:

### PLEASE NOTE:

- The technical committee, SABS/TC 081/SC 08: CONSTRUCTION MATERIALS, PRODUCTS AND TEST METHODS - BITUMEN AND BITUMINOUS PRODUCTS responsible for the preparation of this standard has reached consensus that the attached document should become a South African standard. It is now made available by way of public enquiry to all interested and affected parties for public comment, and to the technical committee members for record purposes. Any comments should be sent by the indicated closing date, either by mail, or by fax, or by e-mail to

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Civil engineering test methods

Part PD1: Determination of permanent deformation and moisture sensitivity in asphalt mixes with the MMLS3

WARNING
This document references other documents normatively.
Acknowledgement

The SABS Standards Division wishes to acknowledge the valuable assistance of the Committee of Transport Officials (COTO), the Institute for Transport Technology, the Department of Civil Engineering, Stellenbosch University, the South African Road Pavement Forum, and the South African National Roads Agency Limited (SANRAL).

Foreword

This South African standard was approved by National Committee SABS/TC 081/SC 08, Construction materials, products and test methods – Bitumen and bituminous products, in accordance with procedures of the SABS Standards Division, in compliance with annex 3 of the WTO/TBT agreement.

This document was approved for publication in xxxx 2016.

SANS 3001 consists of various parts under the general title Civil engineering test methods.

Parts PD of the SANS 3001 series contain methods for the testing of permanent deformation in asphalt surfaces and the performance of bituminous pavement surfaces.

Annexes A and B are for information only.

Compliance with this document cannot confer immunity from legal obligations.

Introduction

This test method was originally issued in 2008 as a best practice protocol guideline (DPG1) for use by practitioners in the asphalt industry in South Africa. The method encapsulates a wide range of research and applications relating to the one-third-scale model mobile load simulator (MMLS3) testing system. Some details are contained in the list of references in the bibliography. Users are advised to use referenced companion tools and equipment where and when appropriate.

This document has been developed to assess the effect of wheel loads on asphalt and bituminous surfacings for roads and to predict pavement rutting performance using the MMLS3 test.
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Civil engineering test methods

Part PD1:
Determination of permanent deformation and moisture sensitivity in asphalt mixes with the MMLS3

1 Scope

1.1 This part of SANS 3001 describes a method to measure deformation performance and susceptibility to moisture damage of bituminous road pavement mixtures, using simulated traffic loading with the one-third-scale model mobile load simulator (MMLS3) load trafficking system under controlled environmental conditions.

1.2 This part of SANS 3001 is applicable to asphalt surfacings and asphalt road base mixtures that contain penetration grade bitumen and modified binders.

1.3 Bituminous surfacing (seals) and mixtures with emulsion and foamed bitumen as binder have also been evaluated with the MMLS3, but are not covered in this part of SANS 3001.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies. Information on currently valid national and international standards can be obtained from the SABS Standards Division.

2.1 Standards

ASTM D3387-11, Standard test method for compaction and shear properties of bituminous mixtures by means of the U.S. Corps of Engineers gyratory testing machine (GTM).

SANS 3001-AS1, Civil engineering test methods – Part AS1: Making of asphalt briquettes for Marshall tests and other specialized tests.

TMH5, Sampling methods for roads construction materials.

2.2 Other publications


1) Available from: http://www.sabita.co.za
3 Definitions

For the purposes of this document, the following definitions apply.

3.1 deformation
distance that the asphalt material has deformed in any specified direction

3.2 downward rut depth
vertical distance between the minimum surface elevation and the original surface profile before starting the formal test trafficking

3.3 heave
vertical distance between the maximum surface elevation and the original surface profile before starting the formal test trafficking

3.4 layer thickness
thickness of the asphalt layer(s) affected by being subjected to trafficking

3.5 load cycle
predetermined set of load applications to allow profilometer measurement interventions

3.6 shoving
movement of the material resulting from a shear force stemming from the trafficking by the load wheels, resulting in sideward or upward (or both) heaving

3.7 test bed
rectangular frame structure that contains and confines core or slab specimens

3.8 total rut depth
deformation of an asphalt layer (pavement, slab, core or compacted specimen) due to stresses and strains resulting from the axle loads and tire pressures applied by MMLS3 trafficking

NOTE. The total rut depth is measured as the vertical distance between the maximum and minimum surface elevation of a cross-sectional profile (the sum of the down rut and any associated upward heaving (see figure 1).
3.9 Trafficking

Application of sequential wheel loads to the asphalt surface by the MMLS3 at a fixed selected speed or frequency.

Figure 1 — Typical profilometer readings

4 Apparatus

4.1 Trafficking machine (MMLS3), with control unit capable of applying the preselected wheel load per axle at a preselected tyre pressure, number of cycles per hour and lateral wander that simulates a Gaussian distribution.

4.2 Profilometer, with mounting plates, screws, and computer and data acquisition equipment able to measure the cross-sectional profile at intervals of at least one reading every 3 mm, reading to 0,1 mm (see figure 1).

4.3 Environmental control system, with a dry heater unit, a wet heater unit and environmental chamber capable of heating and maintaining the slab/specimen temperature to a preselected level with a tolerance of ± 0,5 °C (when required). When used in the field the wet heater shall be fitted with spray nozzles.

4.4 Test bed, for testing cores or compacted specimens in the laboratory (see figure 2).

4.5 Type K/J/T thermocouples, minimum of eight, with data logging equipment able to record temperatures on a minute basis, reading to 0,5 °C.

4.6 Drying oven, capable of maintaining a temperature of 135 °C with continuous draft.

4.7 Gyratory compactor, as described in ASTM D3387-11.

4.8 Rotary coring machine, with diamond coring bit of internal diameter 149,5 mm ± 0,5 mm and water feed to cool the specimen during drilling.
4.9 **Rotary cutting machine**, capable of cutting 150 mm specimens to ensure that the samples conform to the surface regularity requirements. An asphalt table saw with constant water supply and a suitable clamping jig is recommended.

4.10 **Rotary planing (chafing) machine**, capable of trimming 150 mm specimens.

4.11 **Angle grinder**.

4.12 **Emulsified silicon rubber**.


4.14 **Sample containers**, of capacity 50 kg and insulated for storing hot asphalt.

![Test bed diagram with keys](image)

**Key**

1. clamp screw
2. wheel ramp
3. adjustable weir
4. overflow tank
5. water inlet
6. longitudinal clamp
7. briquette
8. clamp
9. water bath
10. wet outlet
11. dry outlet

**Figure 2 — Test bed**

5 **Principles**

The MMLS3 uses a one-third-scale machine to assess performance and in particular permanent deformation of asphalt mixes under repeated traffic loads. The outcome of the test is strongly dependent on the following factors:

a) environmental conditions in the form of temperature, rainfall and ageing;

b) traffic volumes and cumulative load applications;
c) the speed of the vehicles;
d) the layer thickness and pavement structure;
e) specimen preparation and test modes.

The MMLS3 equipment is capable of controlling these factors and the test procedure requires input of these critical data. To assist in determining the various input factors a detailed discussion of the factors is given in annex A and guidelines for the selection of the factors are given in annex B. Reliable results depend on many factors, but useful advice regarding the selection of test modes and equipment is provided in *User Guide: Lessons learnt from applications* (listed under MLS Publications) and related documents (see Bibliography).

NOTE  User Guide: Lessons learnt from applications can be found at 

# 6  Test specimens and locations

## 6.1  General

Testing can be performed in a laboratory and in the field. Tests in the laboratory can be done on constructed slabs or in the test bed on cores and compacted cylindrical specimens. In the field, tests are done on in-situ constructed pavements.

## 6.2  Laboratory compacted specimens

### 6.2.1  General

Asphalt compacted in the laboratory as cylindrical briquettes or slabs can be prepared from either plant mix or raw materials mixed in the laboratory.

### 6.2.2  Briquettes

#### 6.2.2.1  Sample or prepare approximately 50 kg of mix for the preparation of a minimum of nine specimens as described in TMH5 (method MB7), or SANS 3001-AS1. When there is a need to use fewer specimens, dummy specimens from earlier tests or specially prepared material can be used at either end of the test bed to fill the outer spaces.

#### 6.2.2.2  Condition the specimens prepared in the laboratory for 4 h at 135 °C in an oven and then adjust to the required compaction temperature before manufacturing the test specimens or test slabs. Compact the specimens with a gyratory compactor. Alternatively, specimens may be compacted by hammer and mould as described in Manual 13.

### 6.2.3  Test slabs

Construct a base layer to the prescribed thickness and density. Heat the asphalt to the required compaction temperature. Compact the asphalt slab on the base layer to the prescribed thickness and density using the laboratory vibratory roller. To reduce the need for reheating, construct the asphalt as soon as possible after mixing.

NOTE 1  The use of a frame to contain the asphalt slab can assist in controlling the thickness and, by adding a calculated mass of asphalt, the void content.

NOTE 2  Controlling the compaction temperature of the asphalt mix can be simplified by using the 50 kg insulated sample containers to transport plant mix or to keep the asphalt batches hot in the laboratory.
6.3 Cored field samples

6.3.1 Extract nine cores using the rotary coring machine for the one-wheel tracking test with diameters that comply with 6.5.2. When coring is to be limited, extract seven cores for each test, and use dummy cores at either end in the test bed. It is preferable to extract and prepare two extra cores in case some do not comply with specifications.

6.3.2 Set the coring machine perpendicular to the surface of the pavement to ensure that the surface of the core is square with the vertical side of the core. This is necessary to ensure that there are no gaps between the specimen and the adjacent metal side wall when inserted in the test bed. The coring operation requires a constant water supply to prevent excessive heating of the cutting face during the machining operation.

6.3.3 Mark each core taken from an in-service pavement indicating the direction of traffic flow. Trim cores to remove all unwanted lower road layers.

6.4 Storing samples

Protect specimens extracted from a pavement from excessive vibration or jarring of containers during transportation to the laboratory. Packaging in bubble wrap is recommended. Store specimens with the test surface horizontal at a temperature of not more than 20 °C. When storing for more than four days the temperature shall not exceed 5 °C. Record the actual storage time, in days, that the specimens will be stored on the test sheet for possible subsequent diagnostic reviews. Do not stack specimens on top of each other or on other objects.

6.5 Cylindrical specimen preparation

6.5.1 Preparation and compaction

Cylindrical specimens are either prepared and compacted in the laboratory in a mould; or prepared from cores taken from an in-situ pavement with a core drilling machine. Cylindrical specimens in the test bed shall have a diameter of 149.5 mm ± 0.5 mm. Cool the specimens down to 5 °C before handling and machining to ensure that specimens do not lose their shape during the clamping and machining operation. When cutting or grinding, always place the specimen face down (trafficking surface) on the machine table or cutting surface.

6.5.2 Specimen thickness

The specimen may be prepared to a thickness of between 30 mm and 100 mm. Use cutting increments of 5 mm (for example 55 mm, 60 mm, and 65 mm). First cut the raw core to a thickness slightly oversize, to within 1 mm to 2 mm, with the rotary cutting machine and then grind the surface down to the required measurement with a tolerance of ± 0.5 mm using the rotary planing machine.

6.5.3 Specimen sides

Cut two parallel sides 108 mm apart with a tolerance of ± 1 mm. It is important that the two parallel edges are equidistant from the centre of the specimen and it is best to prepare jigs for cutting each side. Finish the specimen sides by grinding the parallel sides to be 105 mm apart with a tolerance of ± 0.5 mm. Without a jig, it is difficult to measure equidistant accurately from the centre of the specimen, so check by measuring the two cut sides, A and B, as given in figure 3, which shall be of equal lengths of 107 mm.
6.5.4 Tolerances

6.5.4.1 Surface undulations or distortions across the surface shall not exceed 2 mm over a length of 20 mm. Establish this by placing a steel rule across a diameter of the face to be trafficked. Repeat measurements across three directions at 45°.

6.5.4.2 Check that the cores have been correctly drilled by comparing distances A1, A2 and A3 to B1, B2 and B3, which shall be equal with a tolerance of ± 1 mm. These three measurements on every side shall be measured as close as possible to the top, bottom and middle of the specimen thickness.

NOTE: When the core is not drilled perpendicular to the pavement, there will be gaps between the specimens in the test bed.

6.5.4.3 Specimens that do not comply with these requirements shall be rejected.

6.5.5 Measurements

Measure the thickness of the test specimen at four points at 90° intervals. Record the average of the four measurements as the thickness of the specimen.

6.6 Preparation of test location

6.6.1 Test bed

6.6.1.1 General

The test bed is used in the laboratory for tests on either cylindrical specimens compacted in the laboratory (see 6.2) or cores taken from the road (see 6.3). The specimens are prepared as described in 6.5.
6.6.1.2 Placing the test specimens

6.6.1.2.1 Place the test specimens in the test bed so that the specimen face to be trafficked is on the bottom surface. Orientate the specimens so that the wheel-tracking path aligns with the direction of traffic flow (where this is known).

6.6.1.2.2 Stack the spacer plates on the top of the specimen so that the surface is flush with the top surface of the semi-circular lateral clamps, ± 0,5 mm. Do this for every specimen and make sure that the nine specimens are flush at their joining edges. When there is a discrepancy, remove the specimen and use a grinding machine to trim the specimen. Repeat until the specimen fits snugly. This is necessary to limit dynamic forces during trafficking.

6.6.1.2.3 Remove the plates and underlying specimens and coat the test bed with emulsified silicone rubber.

6.6.1.2.4 Replace the spacers in the test bed with the specimens on top with the face to be trafficked upwards.

6.6.1.2.5 Lock the longitudinal clamp, indicated in figure 2, and ensure that the specimens are in full contact with one another and the underlying test-bed plate without deforming the specimens.

6.6.1.2.6 Clamp the specimen snugly tight in the y-axis using the semi-circular lateral clamps. Take care not to over tighten the clamps and damage the specimens.

6.6.1.3 Positioning the thermocouples in the test bed

Place the thermocouples between the joints of the respective specimens, as shown in figure 4 and detailed in table 1. Cut slits at the thermocouple positions using the hand-held angle grinder with a blade of 4 mm maximum thickness. Cut the slits 5 mm wide and 5 mm deep. The slit-length to its full depth should end in the middle of the specimen.

Figure 4 — Test-bed thermocouple positions
Table 1 — Location of thermocouples

<table>
<thead>
<tr>
<th>Position</th>
<th>Thermocouple number</th>
<th>Slit cut in core number</th>
<th>Position below core surface</th>
<th>Core thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Core thickness</td>
<td>&lt; 50</td>
</tr>
<tr>
<td>Between cores 1 and 2</td>
<td>TC 1</td>
<td>Core 2</td>
<td>17</td>
<td>25</td>
</tr>
<tr>
<td>Between cores 3 and 4</td>
<td>TC 2</td>
<td>Core 4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>TC 3</td>
<td></td>
<td>17</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>TC 4</td>
<td></td>
<td>–</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>TC 5</td>
<td></td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>TC 6</td>
<td>Bottom</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Between cores 8 and 9</td>
<td>TC 7</td>
<td>Core 9</td>
<td>17</td>
<td>25</td>
</tr>
<tr>
<td>Core 5</td>
<td>TC control</td>
<td>Core 5</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

NOTE 1  TC is thermocouple.

NOTE 2  TC 1 to TC 7 placed on the same side of each core.

NOTE 3  TC control centrally on the edge of the core out of the trafficked path.

NOTE 4  Depending on core thickness TC 4 and TC 5 omitted.

6.6.1.4 Fixing the thermocouples

6.6.1.4.1 Heat 60/70 penetration grade bitumen and crusher dust to 150 °C in a container. Mix the crusher dust 1:3 with the penetration grade bitumen and re-heat to 150 °C.

6.6.1.4.2 Dip the thermocouple into the mix and place into the slit. If necessary, add some bitumen to fill the cavities.

6.6.1.4.3 Make the protruding bitumen flush with the specimen surface using a spatula or, if cooled, grind to remove the excess.

6.6.1.4.4 Fix the thermocouples one by one, waiting for the bitumen to cool sufficiently.

6.6.1.4.5 Epoxy may be used in place of the bitumen crusher dust mix.

6.6.1.4.6 Use duct tape to lead away any protruding thermocouple wire and to keep it from being caught by moving parts during testing.

6.6.2 Field or laboratory slab test area

6.6.2.1 Setting up

Set up the testing area as described in MMLS3, Supplementary items – Operator’s Manual. After establishing the centre lines of the test area, fix the index bars (see figure 5).
6.6.2.2 Positioning the thermocouples

6.6.2.2.1 The 500 mm mark indicated by the index bars is in the centre of the test area. When a field test is done in conjunction with a laboratory test, the thermocouples are installed at distances as best possible to resemble the thermocouples placed in the test bed, for later comparison.

6.6.2.2.2 Drill 4 mm diameter holes (maximum 6 mm) in the middle of the longitudinal centre line (trafficking direction) at depths and distances from the transverse centre line as shown in figure 5 and table 2.

6.6.2.2.3 Place each thermocouple in the corresponding hole with the cables led out perpendicularly to the trafficking direction. When the cables are thicker than 0,5 mm place them in slits cut in the top of the pavement.

6.6.2.2.4 When slits are required, use the angle grinder, with a disc of maximum thickness 4 mm, to cut slits 5 mm wide and 5 mm deep, from the hole to the edge of the testing area. When lateral wander (see 6.6.5) is applied, the slits will need to extend out further, as the width of the test section can increase to a maximum of 230 mm.

### Table 2 — The position and depth of the thermocouple holes

<table>
<thead>
<tr>
<th>Position from transverse centre line</th>
<th>Thermocouple number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>mm</td>
<td></td>
<td>&lt; 50</td>
<td>50 to 75</td>
<td>&gt; 75</td>
<td>mm</td>
<td></td>
</tr>
<tr>
<td>350 left</td>
<td>TC 1</td>
<td>17</td>
<td>25</td>
<td>25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>150 left</td>
<td>TC 2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>TC 3</td>
<td>17</td>
<td>25</td>
<td>25</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>TC 4</td>
<td>–</td>
<td>50</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>TC 5</td>
<td>–</td>
<td>–</td>
<td>75</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>TC 6</td>
<td>Bottom</td>
<td>Bottom</td>
<td>Bottom</td>
<td></td>
<td></td>
</tr>
<tr>
<td>350 right</td>
<td>TC 7</td>
<td>17</td>
<td>25</td>
<td>25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>TC control</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**NOTE 1** TC is the thermocouple.

**NOTE 2** TC control 55 mm from longitudinal centre line – make a small 5 mm slit in the pavement.

**NOTE 3** Depending on layer thickness TC 4 and TC 5 is omitted.
6.6.2.3 Fixing the thermocouples

6.6.2.3.1 Heat 60/70 penetration grade bitumen and crusher dust to 150 °C. At this temperature mix the crusher dust 1:3 with the penetration bitumen and re-heat to 150 °C.

6.6.2.3.2 Dip the thermocouple into the hot bitumen mix, with the necessary length which is to be fixed on the pavement. The end to be inserted into the hole in the pavement might need more mix on it. When the tip of the thermocouple is at the bottom of the hole it shall be fully surrounded with bitumen without air gaps in the hole.

6.6.2.3.3 Fix the protruding cable into the slits. While hot make the protruding bitumen mix flush with the road surface using a spatula. When the mix has cooled and still protrudes, remove the excess with a planing machine or other suitable tool. If the bitumen mix is not efficient epoxy may be used.

6.6.2.3.4 Use duct tape to lead away all protruding thermocouple wires and to keep them from being caught by moving parts during testing. Assemble all the wires at a point and lead them outside the testing area (when using the wet heater unit, lead it outside the spray nozzles), as shown in figure 5. Do not use duct tape on the trafficking area.

6.6.2.3.5 Ensure that the thermocouple wires are fixed to the pavement in such a way that the trafficking wheel does not dislodge the wires, especially at the 90° bend between the hole and the slit.

6.6.3 General preparation

6.6.3.1 Specimens for the test bed shall be machined as described in 6.5, before being installed to fit snugly in position (see figure 2). Secure the specimens in the test bed using the clamps and screws.
6.6.3.2 Before starting the test, preheat the specimens or test section to the prescribed temperature ± 2 °C (see 6.6.4) at the upper thermocouples (17 mm or 25 mm) depth. Monitor carefully and set the dry heater or wet heater unit's temperature controller (TC control, measuring the top surface of the specimen) to about 2 °C above the required temperature at the prescribed depth and heat until the required temperature is reached. This may take more than 12 h to achieve, depending on the circumstances. Do not heat the asphalt surface above 75 °C (TC control) as this might alter the asphalt properties.

EXAMPLE If a temperature of 60 °C maintained at 25 mm depth is required, set the TC control to about 62 °C. Monitor the temperature over time until the temperature at 25 mm depth is stable at 60 °C.

6.6.3.3 Apply one hundred MMLS3 load applications to ensure proper seating of the specimens. Retighten the screws and clamps to secure the seated position.

NOTE Trafficking for seating is not required for field tests.

6.6.3.4 Measure cross-sectional profiles to serve as a reference before test trafficking is started.

6.6.3.5 When wet trafficking is prescribed, use the wet heater unit to recirculate the water during the test. Add water to the test bed to a level of 1 mm ± 0.5 mm above the highest specimen surface. Maintain the water level throughout the test. When applying wet trafficking in the field, use spray and suction nozzles in conjunction with the wet heater unit to recirculate the water over the test section. Spray the water evenly at a constant rate across the test pavement during trafficking. The spray and suction nozzle system forms a dam around the test section. When the surface has a cross slope this requires particular attention and additional mechanisms might be needed to ensure even flow. Maintain the temperature of the water at the selected test level.

6.6.4 Test temperature

Determine the test temperature on the basis of the seven hottest sequential days in a period of one year for the past thirty years (or known record if less) at the site where the mix is to be constructed.

NOTE 1 See A.2.1 for guidelines regarding test temperatures.

NOTE 2 Several research reports about procedures or related issues (or both) have been published (see Williamson and Marais 1975; Deacon et al. 1994; Huber 1994; Everitt et al. 1999; Epps et al. 2002; Epps et al. 2003; Burger and Kröger 2004; Denneman 2007). The Denneman reference is particularly useful for South African conditions.

6.6.5 Lateral wander

The lateral wander of the equipment has been pre-set to produce a Gaussian distribution with an adjustable width. Adjust the trafficked width between 0 mm and 75 mm using the adjustable screw on the MMLS3 control unit. This action can lead to shear and shoving of the material resulting in upward heaving.

NOTE 1 Lateral wander cannot be applied to specimens in the laboratory test bed.

NOTE 2 A setting of 75 mm will result in a maximum trafficked width of 230 mm (i.e. 75 mm left + 80 mm tyre width + 75 mm right). The 75 mm setting will cause the trafficking tyre to move 75 mm to the left and to the right. The Gaussian distribution is achieved by the machine changing position laterally every 25 s. A full Gaussian distribution consists of 16 incremental positions with different distances between each other, closer together in the middle and further apart at the ends.
7 Procedure

7.1 Profilometer readings

7.1.1 Setting up and operation of profilometer

Consult the MMLS3 P900 Profilometer Operator’s Manual for details on the setting up and operation of the profilometer. Before starting a test, set up a fixed profilometer grid as described. This operation is critical as it provides a reference system against which all displacements are measured and compared.

For a test in the laboratory test bed, ensure that the index bars are permanently fixed to the floor in such a way that a profile can be measured through the centre of each briquette (see figure 3).

For a test on a slab or field pavement, ensure that the index bars are installed as indicated in figure 5, and as described in the MMLS3 Operator’s Manual. Up to ten profiles, spaced 50 mm apart, profiles can be measured. Take four profiles, as indicated in figure 5 and described in 7.1.2. Ensure the following:

- a) the index bars are clean and firmly mounted so that the measurement reference points will not move during the entire experiment;
- b) the measuring wheel is clean, as a lump of bitumen on the wheel will cause inaccurate readings;
- c) before each measurement, the path of the measuring wheel on the pavement is free from small loose stones or other objects;
- d) the index bars are removed from their glued on mounting plates after each measurement session and reinstalled for the next session. This is to prevent the index bars from being bumped or damaged, especially when the air nozzles are used to heat or cool the pavement.

7.1.2 Cross sections

7.1.2.1 For a test in the laboratory test bed, take measurements on the seven inner specimens (specimen numbers 2, 3, 4, 5, 6, 7 and 8). Do the seating (see 6.6.3.3) before taking the zero-readings.

7.1.2.2 For a field test use only four cross-sectional positions for measuring. Measure the distances from the transverse centre line (see figure 5), as follows:

- a) −300 mm;
- b) −50 mm;
- c) +50 mm;
- d) +300 mm.

7.1.3 Measuring width and increments

7.1.3.1 For a field test, measure at least 50 mm on either side of the trafficking width to make sure that all heaving is measured. For a test without lateral wander (and also when using the test bed) choose the total profilometer measuring width to be at least 180 mm (80 mm tyre width + 50 mm either side). Lateral movement will depend on the adjustable setting. When lateral wander is set at 75 mm, the total trafficking width will be 230 mm (80 mm tyre + 75 mm either side) and the minimum profile measurement width should be 330 mm.
7.1.3.2 For a test in the laboratory test bed on 150 mm diameter briquettes, measure a total width of 150 mm + 40 mm = 190 mm, to include 20 mm of the top surface of the aluminium clamps on each side of the 150 mm diameter briquette. This can serve as an additional reference point for the measured data.

7.1.3.3 Take readings at 2 mm increments.

NOTE The profilometer measures the required width symmetrically around its centre (see the MMLS3 P900 Profilometer Operator’s Manual for the set-up of the profilometer).

7.1.4 Initial readings

Take zero readings before starting the test. Take readings in accordance with procedures given in the MMLS3 P900 Profilometer Operator’s Manual. When heating is involved, take zero readings when the material is at the correct test temperature. For a test in the test bed, ensure that the seating is in accordance with 6.6.3.3.

NOTE The zero readings are used to normalize all subsequent profile measurements.

7.1.5 Interval of readings

Stop the trafficking and measure cross-sectional profiles at predetermined intervals (see table 3) during the test. Measure a final profile when trafficking is terminated at the end of the test.

7.1.6 Downward rut depth and heaving

Determine and report the depth of the downward rut as well as the heave on both sides of the wheel track using the profilometer readings (see clause 8). When using the laboratory test bed, take only rut measurements, and state this clearly in the test report.

NOTE In some cases, especially with weak material in the laboratory test bed, the heaving may be so excessive that the heaved material has to be removed to be able to take proper profile readings. In such a case the heave should not be reported; it should be recorded that heaved material was removed.

7.1.7 Surface condition

Record the surface condition and take photographs at each profilometer reading interval. In the case of wet trafficking make a careful visual estimation of the percentage of stripping or ravelling.

NOTE Stripping occurs when the binder is detached from the aggregate particles. Ravelling is the loss of aggregate (stone) plucked out from the asphalt surface.

7.2 Test temperatures

7.2.1 Before starting the test, check that the heating equipment is operating correctly and that the specified temperature has been reached (see 6.6.3.2 and 6.6.4).

7.2.2 When the specimen temperature at a depth from the trafficked surface of 17 mm (for specimens 50 mm thick or less) or 25 mm (for thicker specimens) differs by more than ± 2 °C from the prescribed temperature, stop trafficking and only continue when the correct temperature is reached. Record the extent and specific times of the stoppage and time of restarting for possible subsequent diagnostic reviews. Stop the machine with the test wheel off the pavement (move it by hand).

NOTE If left on the pavement for any length of time the wheel will deform the pavement.
7.3 Loading

7.3.1 Run the MMLS3 for one load cycle. The test typically progresses with load application increments up to the preselected total number of load applications as indicated in table 3 or according to the selected speed. The standard total number of load applications is 100 000. For specific purposes the load applications may be increased or decreased.

NOTE 1 It has been found that the rutting performance generally follows a power function relative to trafficking. Extrapolation of fewer load applications might provide results of sufficient accuracy for specific situations.

NOTE 2 The load applications might have to be increased beyond 100 000 applications to explore critical conditions or evaluate performance prediction.

NOTE 3 For wet tests, the number of applications may be adapted to suit the site conditions (see annex B).

NOTE 4 A remote control device for detecting a blow-out of a tyre is available from the equipment supplier.

7.3.2 Monitor and record specimen temperatures using the thermocouples (see 6.6.1.3) at 1 min intervals throughout the test.

7.3.3 Take profilometer readings after each load cycle.

Table 3 — Load applications and increments per load cycle

<table>
<thead>
<tr>
<th>Number of cycle</th>
<th>Number of load applications per cycle</th>
<th>Cycle time (a)</th>
<th>Number of cumulative load applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 000</td>
<td>8.3 min</td>
<td>1 000</td>
</tr>
<tr>
<td>2</td>
<td>1 500</td>
<td>12.5 min</td>
<td>2 500</td>
</tr>
<tr>
<td>3</td>
<td>2 500</td>
<td>21 min</td>
<td>5 000</td>
</tr>
<tr>
<td>4</td>
<td>5 000</td>
<td>42 min</td>
<td>10 000</td>
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<tr>
<td>5</td>
<td>10 000</td>
<td>1 h 23 min</td>
<td>20 000</td>
</tr>
<tr>
<td>6</td>
<td>20 000</td>
<td>2 h 46 min</td>
<td>40 000</td>
</tr>
<tr>
<td>7</td>
<td>30 000</td>
<td>4 h 10 min</td>
<td>70 000</td>
</tr>
<tr>
<td>8</td>
<td>30 000</td>
<td>4 h 10 min</td>
<td>100 000</td>
</tr>
</tbody>
</table>

\(a\) Estimated with a load application rate of 7 200/h. Cycle times will be longer for slower speeds.

7.3.4 Before starting the next load cycle check the following:

a) the temperature of the test specimens, slabs or road surface, and only resume the test after the prescribed temperature has been reached ± 2 °C. Take steps to minimize temperature loss during data collection intervals;

b) all tyre pressures, and ensure that the tyres are still fully inflated before resuming trafficking;

c) binder deposit on the curved end plate of the machine, and remove any binder deposit;

d) when using the test bed, that the entry and exit transition plates are flush with the specimen surfaces, and adjust when necessary;

e) in the case of a dry heating test, that the machine is stable with the nozzles of the dry-heating unit in position.
7.3.5 Apply the next load cycle and repeat until the total number of load applications is reached.

7.3.6 After completion of the last load cycle, take the final profilometer readings and remove the machine. This should be done preferably while the test surface is still hot. Inspect the surface and report the condition.

7.4 End of test

7.4.1 Extract 100 mm cores from the centre of the test specimens, slabs or test pavement for evaluation of structural damage due to the impact of the water during trafficking.

7.4.2 Remove the remainder of the test specimens and clean the test bed or reinstate the road surface.

8 Data processing

8.1 Lateral surface profile

The consolidated profilometer data can be retrieved from the profilometer software, as described in the MMLS3 P900 Profilometer Operator's Manual. A typical file name will be "A0100C", where "A" is the experiment identifier, "0100" indicates that the profiles were measured at position 100 on the index bars, and "C" indicates that it is a consolidated file, with all the profiles measured at this index position during the experiment consolidated into one file. A typical consolidated raw profile data file is given in table 4. Note that downward displacement of the surface of the sample is defined as positive rut.

<table>
<thead>
<tr>
<th>Index bar 0100</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
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<tbody>
<tr>
<td>x</td>
<td>0</td>
<td>1000</td>
<td>2500</td>
<td>5000</td>
<td>10000</td>
<td>20000</td>
<td>40000</td>
<td>70000</td>
<td>100000</td>
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<td>20,065</td>
<td>20,109</td>
<td>20,053</td>
<td>19,909</td>
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<td>19,751</td>
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<td>12</td>
<td>20,125</td>
<td>20,055</td>
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<td>19,855</td>
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<td>20,064</td>
<td>20,072</td>
<td>19,903</td>
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<td>19,786</td>
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<td>20,158</td>
<td>20,117</td>
<td>20,095</td>
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<tr>
<td>18</td>
<td>20,184</td>
<td>20,129</td>
<td>20,143</td>
<td>20,08</td>
<td>19,916</td>
<td>19,823</td>
<td>19,829</td>
<td>19,782</td>
<td>19,606</td>
<td></td>
</tr>
</tbody>
</table>

8.2 Procedure

8.2.1 Subtract the zero readings (as given in column "0" in table 4) at each x-increment from all the readings at that same increment. This will normalize the data and indicate all the vertical displacements relative to the original pavement surface when the zero readings were taken.

8.2.2 Smooth each profile curve by taking a three-point running average (each data point is replaced by the average of itself and the data point before and after it).
8.2.3 Plot the smoothed profile curves and inspect it for irregularities or data errors. If necessary edit the raw data to remove errors. A typical plot, indicating the profile after each load cycle (interval), is given in figure 6.

8.2.4 Determine the rutting depth at the end of each load cycle by picking the lowest point (highest numeric value) on each curve in the region of the wheel track (below the zero line as shown in figure 6).

8.2.5 Determine the left side heave and the right side heave caused by lateral and upward shoving of the material, at the end of each load cycle by picking the highest point (lowest numeric value) on each curve on the left hand side and right hand side respectively of the wheel track.

8.2.6 Repeat the steps in 8.2.1 to 8.2.5 for all the index positions.

8.2.7 Calculate the average rutting and heaving for all the profiles measured at the different index positions for each load cycle (see table 5).

Table 5 — Summary of average vertical deformations

<table>
<thead>
<tr>
<th>Number of cumulative load applications</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>mm</td>
<td>Down rut</td>
<td>Heave left</td>
<td>Heave right</td>
</tr>
<tr>
<td>1 000</td>
<td>mm</td>
<td>mm</td>
<td>mm</td>
</tr>
<tr>
<td>2 500</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>5 000</td>
<td></td>
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<td></td>
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<td>10 000</td>
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<td>20 000</td>
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<td>40 000</td>
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<tr>
<td>70 000</td>
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<td></td>
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<tr>
<td>100 000</td>
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</tbody>
</table>

* Average data for the central seven specimens with the test bed and the average data from the four profile lines when testing in the field.
8.2.8 Plot the average rut values on a log-log graph and fit a power curve (straight line) to the average measured points and extrapolate to one million load applications as indicated in figure 7.

![Average cumulative rut graph](image)

Figure 7 — Average (all index positions) cumulative rut versus cumulative load applications

8.2.9 When applicable, plot left- and right-hand side heave values as described in 8.2.8.

8.2.10 The use of a spreadsheet is recommended to calculate and summarize results. As long as parameters such as the number of data points, x-increment and number of index positions remain the same, new data can simply be imported into the spreadsheet to overwrite old data, and the results are available immediately.

NOTE A copy of a suitable spreadsheet can be obtained from suppliers of the MMLS3 trafficking machine.

8.3 Temperature measurements

Determine the weighted average test temperature, $T_{AVE}$, of each thermocouple using the calculation sheet given in table 6 and the following formula:

$$T_{AVE}(x) = \sum T_{IA}(k) \times Y(k)$$

where

- $T_{AVE}$ is the weighted average test temperature, in degrees Celsius ($^\circ$C);
- $x$ is the specific thermocouple;
- $T_{IA}$ is the interval average temperature, in degrees Celsius ($^\circ$C);
- $k$ is the specific interval;
- $Y$ is the weight factor of each interval average temperature.
Table 6 — Calculation sheet for summary of temperature measurements

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermo-couples</td>
<td>Position</td>
<td>Depth</td>
<td>Load applications</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mm or No.</td>
<td>mm</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>$T_{IA}(k)$</th>
<th>$T_{AVE}(x)^3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>°C</td>
<td>°C</td>
</tr>
<tr>
<td>0 - 2 500</td>
<td>2 500 - 5 000</td>
</tr>
<tr>
<td>0,025</td>
<td>0,025</td>
</tr>
</tbody>
</table>

---

9 Test report

The test report shall contain at least the following information:

a) test conditions including

1) the wheel load, in kilonewtons (kN),
2) the tyre pressure, in kilopascals (kPa),
3) pavement temperature data (see 8.3),
4) the wheel speed (load applications per hour),
5) the type of test: wet or dry,
6) the type of asphalt mix;

b) tabulation of the average rut depth and heave in relation to the number of wheel loads applied, as in table 5;

c) a graph of the surface profile in relation to applied loads, averaged over all the measured profiles similar to figure 6;

d) a log-log graph of the rut depth and, where applicable, the heave together with a fitted power curve and extrapolation to one million load applications similar to figure 7;

e) the surface condition after each load cycle;

---

Notes:

$^a$ Weighted average test temperature ($T_{AVE}(x)$) is the interval average temperature ($T_{IA}(k)$) multiplied by the weight factor ($Y(k)$).

$^b$ TC control is the thermocouple connected to the temperature control unit. The thermocouple is usually set to one value throughout the test set on the control unit. When this value is changed during the test this shall be clearly noted.
f) an estimation of the degree of stripping after each load cycle;

g) a statement about the environmental conditions (ageing, temperature and water applied).
Annex A
(informative)

Factors that affect rutting performance

A.1 General

A.1.1 This annex forms the basis of the methodologies used to evaluate the performance of the asphalt under MMLS3 trafficking. The empirical methodology has been simplified to capture the impact of the various scenarios in terms of a limiting rut depth after 100 000 MMLS3 load applications. This provides benchmarks for establishing acceptable asphalt construction for specified operational conditions during the life cycle of the asphalt layer. The tables in annex B contain proposed guidelines for determining test specifications and performance benchmarks. In B.5 reference is made to the quantitative analytical mechanistic methodology for evaluating performance.

A.1.2 The following factors should be considered when rutting performance is evaluated under MMLS3 trafficking, whether this is done empirically or analytically:

a) the environmental impact;
b) the traffic volume and related axle loads;
c) the traffic speed;
d) the layer thickness and pavement structure;
e) the test mode and specimen preparation;
f) trafficking in the test bed and in the field;
g) the construction quality;
h) the specimen geometry;
i) the number of core specimens;
j) the storage of samples;
k) lateral wander and wet trafficking.

A.1.3 In the former case (see A.1.1) the factors are generally taken into account in an overall manner, whereas they are considered more discreetly with analytical evaluation and performance prediction.

A.2 Environmental impact

A.2.1 Temperature

Temperature is a test parameter that affects the rutting performance of the asphalt directly. Temperature is dependent on a number of factors such as geographic region and elevation. Procedures have been developed to assist with the selection of appropriate critical temperature(s) for testing, based on prescribed analytical procedures (see Williamson and Marais 1975; Deacon et al 1994; Huber 1994; Everitt et al (1999); Epps et al 2002; Denneman 2007).
The test temperature of the deep or deeper asphalt layers should take the thermal gradient in the asphalt with depth into account when testing asphalt used below the wearing course. It should be noted that some practitioners opt to keep 50 °C as the minimum test temperature. The temperature of the water on the underside of the test bed should be set to establish and maintain the specified thermal gradient.

The temperature during the initial phase of rutting is of critical importance since it controls the extent of the initial rut depth. This in turn controls the limit reached during the secondary phase. The latter is of course dependent on the rutting rate, which is also a function of trafficking temperature. The net effect of these two phases of trafficking (see figure A.1) ultimately determine the rutting performance subject to the other factors given in A.2.2 and A.2.3.

A.2.2 Rainfall

Wet trafficking can increase the rutting of asphalt. It can also damage the structure of the asphalt. Rainfall patterns should be considered with respect to frequency, duration and intensity relative to trafficking. This provides the basis for selection of the nature of the wet trafficking that should be used. Decisions relate to the extent of wet trafficking and the selection of a trafficking temperature (see A.6).

NOTE 1 This figure has been adapted from Hugo and Gerber (2008).

NOTE 2 The turning point between initial rutting and secondary rutting (see A.2.1) lies between three thousand and five thousand cumulative load applications.

Figure A.1 — Comparative performance of two mixes differing in terms of critical zone effects on secondary rutting after 10 000 cumulative load applications

A.2.3 Ageing

Ageing is a factor that is time and region dependent and it can have a profound effect on the performance of an asphalt layer in terms of rutting. Early trafficking is therefore a factor that affects performance. Traffic during the latter part of the life cycle would have less effect.
Material characteristics that provide insight into the extent of ageing are not always readily available. In general ageing is accounted for by reducing the expected rutting as finally estimated from the MMLS3 rutting performance by 30%. This is based on the progressive increased stiffness over time due to ageing. If the asphalt that is being tested is already aged due to the passage of time, the rate of rutting relative to trafficking will be less throughout the test.

Heavy trafficking shortly after paving would require specific consideration such as special attention to the use of high resistant mixes or, if feasible, diverting the traffic briefly during the vulnerable period (see Epps et al 2002).

To account for this rationally, it is important to record the age of the asphalt at the time of testing. It is proposed that the status be categorized and recorded in terms of the following time frames for possible subsequent diagnostic reviews:

a) one to seven days after construction;
b) one month after construction;
c) six months or longer after construction.

Preconditioning of specimens or test sections before testing (if applicable) should be reported.

A.3 Traffic volume and related load applications

Traffic volume and related load applications should be selected to reflect the respective statistics pertaining to critical temperature phases. This is generally when the asphalt is above 40 °C. Furthermore, the early life traffic, i.e. during the first 30 days, should be considered carefully since it impacts on the critical primary rutting phase. Critical trafficking is generally taken as prevalent only during a portion of the day, in the life cycle of the pavement.

The extent of critical trafficking volume is also affected by lateral wander of the traffic. This reduces the number of load applications at a specific location in the transverse profile. It also affects the way in which the asphalt is moulded transversely. Although the distribution is random, the resulting deformation profile is normally of a Gaussian format. With extremely vulnerable mixes it can, however, manifest in uneven sharp vertical displacements across the profile. (See A.6.7 for lateral wander.)

A.4 Traffic speed

The speed of trafficking should be selected to reflect the application of the asphalt layer(s) whether it is for highways or airports. Further distinction should be made to account for factors such as average speed, gradients, truck traffic volume, traffic flow rate and stop-start conditions. The following categories are recommended for the respective conditions:

a) flat (level) free-flowing traffic;
b) rolling gradients and free-flowing traffic with high truck volumes;
c) slow channelized traffic on steep inclines and highway intersections;
d) free-flowing airport runways and taxiways with high contact stresses;
e) airport aprons, stop-start taxiways and runway thresholds (-150 m).
The maximum equivalent MMLS speed of 7 200 load applications per hour is regarded as relating to free-flowing highway speed in excess of 27 km/h; slower speeds are used progressively to simulate the other more strenuous situations. The most severe condition is 1 800 load applications per hour, and is considered to simulate complex and high stress conditions such as intersections, airport aprons, stop-start taxiways and runway thresholds. See A.6 for other factors relating to the test mode.

A.5 Layer thickness and pavement structure

Layer thickness relates to the comparative stresses between MMLS3 and full-scale trafficking tyres. The thinner the layer, the closer the comparative relationship. The result is that the rutting under MMLS3 trafficking relative to full-scale trafficking generally should be proportionately increased as the layer thickness is increased.

The thinner the asphalt layer, the more the total surface rut of the structure may be influenced by underlying layers which are often non-asphalt. Hence it is important to measure the rutting directly related to the asphalt. For this a pin is anchored under the asphalt layer (see figure A.2) to enable the rutting in the asphalt to be determined separately from settlement underneath (see Hugo et al 2004). This might limit the allowable rut depth in the asphalt.

Tyre pressure plays an important role in the performance of the asphalt material especially when fresh. Comparative measurement with the stress-in-motion (SIM) device has identified tyre pressures that cause similar contact stresses on the asphalt surface. A tyre pressure of 800 kPa is considered appropriate under a high percentage of very heavy truck traffic. This may cause
excessive wear on the MMLS3 tyres. Therefore a slightly lower value of 750 kPa or 700 kPa should be used when the heavy percentage is not too high. The wheel load should be considered since it affects the footprint. With the high tyre pressure a load of 2.9 kN is used. When the lower values are used the load is reduced to 2.7 kN per axle. The resulting performance with the respective pressures and loads is then used for life cycle performance prediction. The layer thickness for testing with the MMLS3 should not exceed 150 mm owing to the limited depth of the stress profile related to the tyre size. The nominal maximum aggregate size (NMAS) should be less than 50 % of the layer thickness of the asphalt.

A.6 Test mode and specimen preparation

A.6.1 General

The test mode and method of specimen preparation influence the performance of asphalt layers in terms of rutting and damage under wet trafficking.

A.6.2 Trafficking in the test bed and in the field

Recent studies have shed further light on the relationship between performance results resulting from testing cores in the test bed and the parent material in the field (with similar preparation of the mix). Previously it was reported that the field rutting results are slightly more than results from laboratory test beds (see Molenaar et al 2004). It has now been found that the results are closer to being equal provided that the conditioning of the asphalt before and during testing is the same (see Hugo and Gerber 2008). This is possibly as a result of the bottom heating of the test bed using the water heating system. It might, however, be dependent on the layer thickness, which in turn influences the stress distribution in the layer. Likewise, the laboratory compacted specimens (other than specimens prepared by roller compaction) rut less than cores. The relationship was reported (see Molenaar et al 2004) as 1.2:1 for surface mixes and 1.55:1 for base course mixes.

A.6.3 Construction quality

Factors relating to construction affect rutting performance. The following should be borne in mind:

a) poor or excessive compaction, whether variable or not;

b) segregation (which would affect rutting);

c) the impact of water during trafficking;

d) variation in the mix composition in terms of aggregate and binder;

e) variation in the nature and quality of the binder.

A.6.4 Specimen geometry

Cores from a standard 150 mm diameter coring barrel are often unsatisfactory because they are either of diameter less than 149 mm or more than 150 mm. Particular care should therefore be taken when specimens are extracted for MMLS3 testing. The core diameter should be checked on site before sending to the laboratory.

A.6.5 Number of core specimens

Consider extracting twelve cores, to allow one core to be tested for volumetrics and availability of spares in case of damage during shipping.
A.6.6 Shipping of samples

Samples are often shipped internationally by courier. Allow the samples to cool to ambient temperature before shipping, to avoid them being classified as dangerous goods.

A.6.7 Lateral wander and wet trafficking

Generally, lateral wander has been considered less damaging than channelized trafficking (see White et al 1999). To simulate the effect of lateral wander, the accelerated pavement testing (APT) trafficking can be distributed transversely. This is normally done by moving the wheel progressively transversely across a selected width during the trafficking to simulate a Gaussian distribution. With extremely vulnerable mixes this would not simulate the situation during the initial phase of testing depending upon the moulding of the asphalt under shear. Generally this is not attempted with normal APT for the sake of reaching trafficking goals quicker.

Lateral wander on asphalt with a thickness of 40 mm under high temperature can cause significantly more damage to the asphalt in terms of rutting than channelized trafficking. It might be more conservative to consider doing tests on thin asphalt layers under critical trafficking conditions.

As stated above, wet trafficking can increase the extent of asphalt rutting. Likewise, the structural integrity can be affected even more so with lateral trafficking wander. However, it is important to select the period of wet trafficking with due regard to the specific climatic situation. In dry areas it might be unnecessary to test in the wet mode. Where the rain only occurs during a part of the year in showers of short duration, the testing mode could be varied to have alternate dry and wet cycles for trafficking to simulate the rain pattern.

Wet trafficking tests can either be conducted in the test bed in the laboratory or in the field. In the latter case a dam is constructed around the test section and water is circulated via a closed-loop pipe system. In both cases the same pump and water heating system is used. The water is allowed to flow over the asphalt at a depth of approximately 1 mm during trafficking. Lateral wander is not feasible in the test bed and in specific cases it might warrant field tests with the MMLS to gauge the impact of the lateral wander.

The trafficking temperature is primarily determined by the temperature of the water. This in turn is selected in relation to the environment. Clearly water at 50 °C would yield conservative results while 25 °C would be the least conservative but possibly more representative of long duration rain spells. The final evaluation relates to loss of stiffness or fatigue life of the trafficked asphalt versus untrafficked asphalt.

A.6.8 Effect of initial untrafficked structure, composition and condition on rutting

As stated in A.2.1, rutting generally comprises two phases that should be considered when evaluating life cycle performance, namely the primary and secondary phases. The primary phase is indicative of the effect of voids and early tenderness of the mix. The effect can be very serious since it affects the time at which a critical rut depth might be reached. It might also affect the rutting rate with the same effect. It is important to capture the potential risk by determining the voids in the mix before and after trafficking.

To normalize comparisons and take account of the pavement condition after initial trafficking, untrafficked MMLS test specimens should be compacted to 5 % voids in the mix (± 0.3 %). Permeability tests could also be done to identify whether the mix is likely to be subject to water infiltration during trafficking (see annex B). The rutting rate generally stabilizes after 10 000 load applications unless trafficking conditions change.
Comparison of performance can therefore be made by considering the extrapolated (or interpolated) performance after a selected trafficking pattern or by comparing rutting rates under similar conditions with due regard to the primary consolidation phase on a log-normal basis.
Annex B  
(informative)

Guidelines for determining test specifications and performance benchmarks

B.1 General

The empirical evaluation of rutting performance is based on comparative studies between MMLS trafficking and full-scale accelerated pavement testing. Case studies date back to 1999 with tests in Texas, Nevada, Alabama and very recently South Africa.

The principle assumption is that the performance can be gauged from the actual life cycle performance under conventional trafficking of full-scale test pavements or full-scale controlled simulated conventional trafficking. The factors discussed in annex A serve to adjudicate whether conditions were similar or taken into account in evaluating the relative performance under the different modes of trafficking (or both).

The evaluation follows a logical process for considering the respective situations. Guidelines have been established for deciding whether performance under MMLS trafficking yielded acceptable levels of performance of pavements that were investigated. The guidelines have been utilised in South Africa in a wide variety of regions and trafficking conditions. Long-term performance has been monitored by surveillance and reports have been confirmed of successful applications. In cases where there was still doubt, long-term monitoring procedures were established under applicable guarantees.

To ensure that all factors are available for consideration, it is imperative that pavement engineers carefully select the test parameters that are to be used for evaluating quality of asphalt mixes. This applies whether for design or construction evaluation. Clients, consultants, contractors and testing laboratories should bear this in mind. To assist in this process tables B.1 to B.3 have been developed for capturing essential information when MMLS testing is requested or considered. These are set out in this annex.

The empirically established protocols for adjudicating MMLS test results and related rutting performance levels of asphalt layers are set out in table B.4 and table B.7. It should be noted that the protocols have been compiled by taking account of speed of trafficking, layer thickness, contact stress and stress distribution within the asphalt. In the case of the 40 mm layer the rutting limits were slightly relaxed to take account of the potential for greater vulnerability of the asphalt due to ageing.

Users of the protocol should note that the guidelines already take account of the mode of trafficking with respect to channelization and lateral wander when tests are conducted on slabs, whether in the field or in the laboratory. In these instances no further adjustments should be made to the performance findings, otherwise compensation will be duplicated. However, when trafficking is carried out on asphalt on specimens in the test bed, adjustments would still have to be made to account for lateral wander.

B.2 Interim protocol for evaluating moisture damage

Guidelines for establishing criteria for evaluating moisture susceptibility or damage to asphalt pavements using wet trafficking after 100 000 applications at 50 °C on heated wet MMLS3 axles are as follows:

a) semi-circular bending test (SCB) – residual tensile strength of hot mix asphalt (see Smit et al (1997)), 80 %;
b) spectral analysis of surface waves (SASW) – residual stiffness (see Lee et al 1997), 80 %;
c) semi-circular bending test (SCB) – fatigue ratio 50 % for hot mix asphalt.

Composite pavements require special consideration to evaluate entrapment of water.

Permeability measurements can be utilized to evaluate the ease of access of water into asphalt and possible effects on performance.

**B.3 Specimen preparation and trafficking**

Specimen preparation and trafficking should be done in accordance with the instructions in tables B.1, B.2 and B.3.

**Table B.1 — Specimen preparation and trafficking – Part 1**

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
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<th>4</th>
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<th>6</th>
<th>7</th>
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<tbody>
<tr>
<td><strong>Instructions for specimen preparation and trafficking</strong></td>
<td>Compaction preparation</td>
<td>Laboratory</td>
<td>Field</td>
<td></td>
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<tr>
<td>Compaction preparation</td>
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<td>Gyratory</td>
<td>Roller</td>
<td>Roller</td>
<td>Roller</td>
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<td></td>
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<tr>
<td>Cylindrical mould</td>
<td>Slab</td>
<td>Slab</td>
<td>Slab</td>
<td>Slab</td>
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<tr>
<td>Voids in mix (target – unless standard 5 %)</td>
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</tr>
<tr>
<td>Trafficking</td>
<td>Channelized</td>
<td>Wander</td>
<td>Channelized</td>
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**Table B.2 — Specimen preparation and trafficking – Part 2**

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</tr>
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<td>Test conditions</td>
<td>Temperature °C</td>
<td>Temperature °C</td>
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<td>Moisture</td>
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<td>Dry</td>
<td>Wet</td>
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<tr>
<td>* Surface</td>
<td>Inundate/Spray</td>
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<tr>
<td>* Internal</td>
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</tr>
<tr>
<td>By inundating</td>
<td>Y</td>
<td>N</td>
<td></td>
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</tr>
<tr>
<td>Other (e.g. by means of suction) report details</td>
<td>Y</td>
<td>N</td>
<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Test temperature</td>
<td>Artificial heating</td>
<td>Y</td>
<td>N</td>
<td></td>
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<tr>
<td>* Surface</td>
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<tr>
<td>* Minus 17 mm</td>
<td>* Minus 20 mm</td>
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<tr>
<td>* Minus 34 mm</td>
<td>* Minus 50 mm</td>
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Table B.3 — Specimen preparation and trafficking – Part 3

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<th>9</th>
</tr>
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<tr>
<td>Trafficking wheel load</td>
<td>kN</td>
<td>2.7</td>
<td>2.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tyre pressure at 25 °C using standard diamond tread tyre</td>
<td>kN/m²</td>
<td>700</td>
<td>750</td>
<td>800</td>
<td>Other</td>
<td></td>
<td></td>
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<tr>
<td>Tyre tread (standard diamond)/Other</td>
<td>Diamond</td>
<td>Y</td>
<td>N</td>
<td></td>
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<tr>
<td>Load applications per hour</td>
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<td></td>
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<tr>
<td>1 800</td>
<td>2 400</td>
<td>3 600</td>
<td>7 200</td>
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</tr>
<tr>
<td>Airport aprons, taxiways and runway thresholds</td>
<td>Steep highway gradients/intersections</td>
<td>Rolling gradients and &gt;&gt;trucks/fast free-flowing airport runways and taxiways</td>
<td>Free-flowing highway speed</td>
<td>Select</td>
<td>1 800</td>
<td>1 800</td>
<td>1 800</td>
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<td>7 200</td>
<td>7 200</td>
<td>7 200</td>
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<tr>
<td>Boundary conditions</td>
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<tr>
<td>Compacted HMA + tack coat (slab – field/laboratory)</td>
<td>Y</td>
<td>N</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Metal mould + emulsion interface (test bed in laboratory)</td>
<td>Y</td>
<td>N</td>
<td></td>
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</table>

NOTE: HMA is hot mix asphalt.

B.4 Proposed empirical protocols

The guidelines to the Empirical Protocols in tables B.4, B.5 and B.6 should be carefully considered when test specifications and performance benchmarks are selected and the findings are interpreted.

Table B.4 — Proposed empirical protocols for acceptable rutting performance

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
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</thead>
<tbody>
<tr>
<td>Proposed empirical protocols for acceptable rutting performance, HMA &gt;90 mm</td>
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<tr>
<td>Laboratory</td>
<td>Field</td>
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<tr>
<td>Maximum rutting under trafficking to 100 000 cumulative load applications mm</td>
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<td></td>
<td></td>
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<tr>
<td>Compaction preparation</td>
<td></td>
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<td></td>
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<tr>
<td>H</td>
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<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>Free-flowing highway speed</td>
<td>2,5</td>
<td>2,5</td>
<td>3</td>
<td>3</td>
<td>3,2</td>
<td>3</td>
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</tr>
<tr>
<td>Rolling gradients &gt;&gt; trucks</td>
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<td>2,5</td>
<td>3</td>
<td>3</td>
<td>3,2</td>
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<tr>
<td>Fast free-flowing airport runways and taxiways</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Steep gradients/intersections</td>
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### Table B.5 — Proposed empirical protocols for acceptable rutting performance

HMA between 75 mm and 90 mm thick

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
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<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airport aprons/stop-start taxiways</td>
<td>1,5</td>
<td>1,5</td>
<td>1,8</td>
<td>1,8</td>
<td>2</td>
<td>1,8</td>
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</tr>
<tr>
<td>Trafficking mode</td>
<td>C</td>
<td>C</td>
<td>C</td>
<td>C</td>
<td>W</td>
<td>C</td>
<td>W</td>
</tr>
</tbody>
</table>

**NOTE 1** HMA is hot mix asphalt.

**NOTE 2** Compaction preparations: H is hammer, G is gyratory and R is Roller.

**NOTE 3** Trafficking modes: C is Channelized and W is Wander.
### Table B.6 — Proposed empirical protocols for acceptable rutting performance  
HMA between 60 mm and 75 mm thick

<table>
<thead>
<tr>
<th>Laboratory</th>
<th>Field</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. rutting under trafficking to 100 000 cumulative load applications (mm)</td>
<td></td>
</tr>
<tr>
<td>Compaction preparation</td>
<td>H</td>
</tr>
<tr>
<td>Free-flowing highway speed</td>
<td>2.0</td>
</tr>
<tr>
<td>Rolling gradients &gt;&gt; trucks</td>
<td>2.0</td>
</tr>
<tr>
<td>Fast free-flowing airport runways and taxiways</td>
<td>1.6</td>
</tr>
<tr>
<td>Steep gradients/Intersections</td>
<td>1.6</td>
</tr>
<tr>
<td>Airport aprons/stop-start taxiways</td>
<td>1.5</td>
</tr>
<tr>
<td>Trafficking mode</td>
<td>C</td>
</tr>
</tbody>
</table>

**NOTE 1** HMA is hot mix asphalt.
**NOTE 2** Compaction preparations: H is hammer, G is gyratory and R is Roller.
**NOTE 3** Trafficking modes: C is Channelized and W is Wander.

### Table B.7 — Proposed empirical protocols for acceptable rutting performance  
HMA between 40 mm and 60 mm thick

<table>
<thead>
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<th>Laboratory</th>
<th>Field</th>
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</thead>
<tbody>
<tr>
<td>Max. rutting under trafficking to 100 000 cumulative load applications (mm)</td>
<td></td>
</tr>
<tr>
<td>Compaction preparation</td>
<td>H</td>
</tr>
<tr>
<td>Free-flowing highway speed</td>
<td>2.5</td>
</tr>
<tr>
<td>Rolling gradients &gt;&gt; trucks</td>
<td>2.3</td>
</tr>
<tr>
<td>Steep gradients/Intersections</td>
<td>2.0</td>
</tr>
<tr>
<td>Trafficking mode</td>
<td>C</td>
</tr>
</tbody>
</table>

**NOTE 1** HMA is hot mix asphalt.
**NOTE 2** Compaction preparations: H is hammer, G is gyratory and R is Roller.
**NOTE 3** Trafficking modes: C is Channelized and W is Wander.
B.5 Quantitative analytical evaluation of rutting performance

The quantitative analytical evaluation of rutting performance is based on comparative studies between MMLS trafficking and full-scale accelerated pavement testing. The same case studies as those used for the empirical evaluation were considered.

Research that relates to dimensional analysis pertaining to the MMLS3 work on scaled pavements has been reported and it is concluded that even when full similitude is not satisfied it is possible to obtain valid results that can be extrapolated to predict prototype performance if one were interested primarily in the behaviour of the asphalt layer.

For more insight into the application of this technology it is strongly recommended that reference be made to User Guide: Lessons learnt from applications, listed under MLS Publications and related documents (see bibliography).
Bibliography

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


MLS Publications and Related Documents.


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