

AUSTROADS TEST METHOD AG:AM/T009

PAVEMENT RUTTING MEASUREMENT WITH A MULTI-LASER PROFILOMETER

1 SCOPE

This test method defines the procedure for measuring the rutting of road pavements, determined by the direct measurement of the transverse profile of the road surface using a vehicle-mounted laser based non-contact device (i.e. a multi-laser profilometer). The device must have a sufficient number of lasers to produce an accurate representation of the transverse profile to a minimum width of three metres.

Rutting collected using this test method is expressed in terms of a maximum rut depth for each wheelpath. An optional addition is the collection of the maximum lane rut depth.

A single test measurement produced by this method is the average rut depth over a given length of road (typically 20 or 100 m).

Multi-laser profilometers used in accordance with this Test Method are operated by a designated 'operator', who is responsible for all aspects of the test and, usually, a vehicle 'driver'. The driver is responsible for following the instructions of the 'operator' and for driving the profilometer vehicle in a safe and legal manner.

This test is often conducted in conjunction with the measurement of road pavement roughness and surface texture depth.

This test method does not address all occupational health and safety issues associated with its use. It is the responsibility of the user to operate in accordance with appropriate legislation.

Annex 1 of this Test Method outlines, in general terms only, some of the hazards and precautions relevant to the use of lasers in road condition measurement. This information has been included to raise awareness of issues and does not override safety warnings/procedures specified by equipment suppliers or other relevant work practices or standards. Refer to equipment documentation and AS 2211:2004 (Standards Australia 2004) for further information.

2 REFERENCED DOCUMENTS

Austrroads Test Method AG:AM/T010. *Validation of a multi-laser profilometer for measuring pavement rutting (reference device method)*. March 2011.

Austrroads Test Method AG:AM/T011. *Validation of a multi-laser profilometer for measuring pavement rutting (loop method)*. March 2011.

International Organization for Standardization (ISO) 1993, *International vocabulary of basic and general terms in metrology*, 2nd edn, ISO, Geneva.

International Organization for Standardization (ISO) 2005, *Quality management systems – fundamentals and vocabulary*, ISO 9000:2005, ISO, Geneva.

Standards Australia (2004). *AS/NZS 2211:2004. Safety of laser products*. (Standards Australia: Sydney).

3 DEFINITIONS

(a) Pavement rutting

A pavement defect that is a characteristic of the transverse profile of a pavement which takes the form of a longitudinal depression, usually occurring in one or both wheelpaths.

(b) Transverse profile

Transverse profile is the shape of a pavement surface measured from a horizontal datum plane transverse to the direction of traffic flow.

(c) Multi-laser profilometer

A multi-laser profilometer (or multi-laser profiler) is a vehicle fitted with a laser-based measurement system consisting of multiple lasers that measures and records the transverse road profile.

(d) Wheelpath

The wheelpath is the lateral or transverse location of the survey vehicle's tyre within the survey lane.

(e) Rut depth

Rut depth is a measure of the pavement rutting determined from the shape of the transverse profile. It may be expressed as follows:

- wheelpath rut depth - the maximum rut depth in each wheelpath or either half of the transverse profile
- lane rut depth – the maximum rut depth across the entire transverse profile.

(f) Straight edge

A straight metal box section with a defined length that is laid across pavement ruts.

(g) Calibration

ISO (1993) defines 'calibration' as:

[a] set of operations that establish, under specified conditions, the relationship between values of quantities indicated by a measuring instrument or measuring system, of values represented by a material measure or a reference material, and the corresponding values realised by [measurement] standards.

(h) Validation

ISO (1994) defines 'validation' as:

confirmation, through the provision of objective evidence that requirements for a specific intended use or application have been fulfilled.

4 EQUIPMENT

The following equipment is required:

(a) A multi-laser profilometer consisting of the following:

- a vehicular platform capable of transporting testing equipment, mounting the transverse profile measuring equipment and travelling at a range of speeds up to the limit of the operating range of the profile measuring equipment
- multiple displacement transducers (laser devices) which measure the distance between a horizontal datum and the travelled surface
The displacement transducers shall be mounted to ensure mid-range operation during normal operation.
Note: The measurement system must have a sufficient number of lasers to produce an accurate representation of the transverse profile to a minimum width of three metres.
- a distance measuring transducer capable of measuring the distance travelled to an accuracy of $\pm 0.1\%$
The transducer shall provide input to the data logger to record the distance travelled from the start of the collection survey.
- a data logger capable of continuously capturing the output data from the transducers at known equal intervals, not greater than 250 mm.

(b) Manufacturer's User Manual.

(c) Flat base plates, gauge blocks and any other equipment required by the manufacturer's User Manual for the calibration of the laser displacement transducers.

5 CALIBRATION AND VALIDATION

5.1 Equipment Calibration

5.1.1 Distance Transducer

- (a) The distance transducer must be calibrated in accordance with the manufacturer's specification.
- (b) The calibration factor and associated information, such as the date and time of calibration, is then stored and used for all subsequent testing until such time as a new distance calibration is performed.
- (c) Distance calibration must be performed whenever a distance transducer is fitted on the vehicle and immediately following any change to the distance transducer or change to any part of the host vehicle that may interfere with the existing calibration constant (e.g. change of wheels or tyres).

5.1.2 Laser Displacement Transducers

- (a) The laser displacement transducers must be calibrated in accordance with the manufacturer's requirements (refer manufacturer's User Manual).
- (b) The transducers must be calibrated immediately following any change to the laser transducers or a change to any part of the host vehicle that may interfere with the existing calibration.

5.2 System Validation

A system validation must have been undertaken. In the absence of other specified requirements, the following must be applied:

- (a) Validation of distance measurement must be conducted in accordance with AG:AM/T005.
- (b) Validation of rutting measurement must be carried out in accordance with Austrroads Test Method AG:AM/T010 or Test Method AG:AM/T011.
- (c) At any stage during a data collection exercise the last successfully passed validation must be within the last 12 months.

6 PROCEDURE

6.1 Pre-test Set-up

- (a) If the laser equipment is of a demountable design, calibrate the vertical distance transducers using the step gauge block and flat plates each time the lasers are refitted to the vehicle.
- (b) Ensure that the serial numbers (or other information that allows traceability to calibration documentation) are recorded for all sensors.
- (c) Perform manufacturer's operational validation procedure ('straight edge test') (refer to Section 6.2, and manufacturer's User Manual).

6.2 Operational Validation Procedure ('Straight Edge Test')

- (a) A manufacturer's operational validation test (commonly known as a 'straight edge test') must be performed before the start of each day's testing (refer manufacturer's User Manual).
- (b) This test verifies the correct operation of the laser displacement transducers and their associated electronics. A metal straight edge is placed (or hung) at a fixed distance from the lasers so that the surface of the straight edge is close to the middle of the lasers' operating range. The test simulates a vehicle travelling along a completely flat transverse profile and, as such, the measured rut depth should be zero. However, due to electronic noise and other factors a negligible rut depth is usually recorded, i.e. less than 1 mm.
- (c) Throughout the 'straight edge test', rutting values greater than 1 mm are unacceptable, and survey testing must not commence until the system is re-calibrated or the cause(s) for the high reading has been identified and corrected.

6.3 Rutting Survey

- (a) The operator must follow the manufacturer's instructions for the use of the equipment (refer manufacturer's User Manual).
- (b) The lane to be surveyed is called the 'test lane'. For routine network surveys, unless otherwise directed, the test lane shall be that lane that is used by the majority of the traffic.

For most roads this coincides with the outer/slow/kerb lane. The median lane shall be tested if parked vehicles obstruct the outer lane; this must be noted and reported.

- (c) The vehicle must be driven in the usually trafficked wheelpaths.
- (d) Throughout the survey the vehicle must be driven in a smooth manner, and care must be taken to ensure that the speed of travel is within the manufacturer's operating range wherever possible.
- (e) Data must be collected with reference to the pre-specified referencing system, and the location of any reference points measured during the survey noted in the data reporting. The start point of the survey must be defined prior to commencing the survey.
- (f) Following the instructions in the manufacturer's User Manual, measure the surface profile across each wheelpath in the test lane, travelling at a relatively constant speed, with the centre of the vehicle coinciding with the mid-point between the wheelpaths of the lane being surveyed.
- (g) Testing must be terminated if conditions are such that difficulty is encountered maintaining the required test lane and/or minimum test speed resulting in the collection of invalid data.
- (h) No attempt should be made to avoid pavement defects unless they are likely to damage the vehicle and/or jeopardise safety.
- (i) Testing must not be performed during periods of rain or where the road surface is wet. If a localised section of wet road is encountered it must be noted and/or flagged (Section 6.4). Arrangements shall be made to test the section when weather conditions are more favourable, if required.

6.4 Factors Affecting the Test

- (a) There are a range of factors that may affect rutting measurements, and when encountered during surveys, the relevant test result must be marked and reported with a note or flag. Example factors include:
 - deviation from the test lane
 - test speeds outside the operating range of the equipment, especially low speeds
 - narrow seals
 - hard acceleration/deceleration/cornering
 - tortuous road geometry
 - bridge abutments/expansion joints
 - cattle grids
 - timber/grid bridge decks
 - rail tracks and crossings
 - access pit covers
 - local area traffic management installations, e.g. speed humps, roundabouts, etc.
 - localised areas of free standing/flowing water on the road surface
 - localised areas of contamination of the road surface, e.g. mud, debris, etc.
- (b) Record any unusual features and events that might influence the results.

6.5 Laser Configuration

The number of lasers mounted on the survey vehicle will impact on both the level of detail of the transverse profile recorded and also the width of the profile.

For safety reasons it is recommended that the lasers are mounted within the maximum legal width for a vehicle. This may necessitate mounting the outer lasers on an angle to give the desired width of measurement.

It is recommended that a minimum of 11 lasers be used to cover as a minimum a three metre transverse profile. The preferred configuration is shown in Figure 6.1.

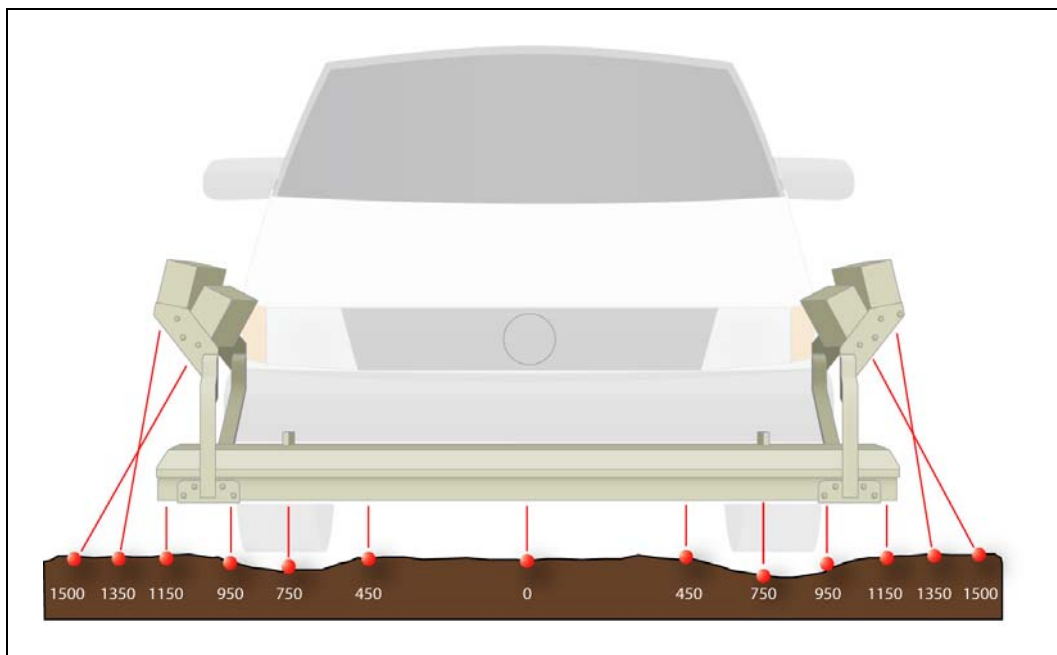


Figure 6.1: Preferred configuration of lasers for measurement of rutting (distances in mm)

7 CALCULATIONS

The straight edge and taut wire models for measuring rut depths are shown in Figure 7.1.

7.1 Required – Wheelpath Rut Depths

- For each 100 m section (or less, if required) being tested, calculate the wheelpath rut depth. This is defined as the average maximum rut depth in each wheelpath (either side of the centreline of the multi-laser profilometer). If the maximum rut depth occurs at the centre laser it shall be included in the driver's side wheelpath.
- The straight edge method must be used. In this method an imaginary straight edge of a defined length is moved across the transverse profile and the maximum gap under the straight edge (between contact points) measured in each wheelpath. Unless otherwise specified, the length of the straight edge must be 2 metres.
- For each 100 m section (or less, if required), the standard deviation of the rut depth measurements, for each wheelpath, must also be calculated.

- (d) Additionally for each 100 m section (or less, if required), report the percentage of ruts that fall into the following series of rut bins: >0 and ≤ 5 , >5 and ≤ 10 , >10 and ≤ 15 , >15 and ≤ 20 , >20 and ≤ 25 , >25 and ≤ 30 , >30 and ≤ 35 , >35 and ≤ 40 and >40 mm. Additional rut bins may be used, but the bins shown here must be used as a minimum.
- (e) The algorithms used to calculate rut depth will vary and in most instances remain the intellectual property of the equipment manufacturer. However, reported rut depths should represent expected values.

7.2 Optional – Lane Rut Depth

In addition to calculating the rut depth in each wheelpath the lane rut depth, defined as the average maximum rut depth across the entire transverse profile, may also be calculated.

The lane rut depth or the rut depth in each wheelpath may also be calculated using the taut wire method (also known as the stringline method) – an imaginary wire is stretched across the transverse profile enveloping the high points and fixed at either end. Rutting is defined as the maximum gap under the string line in each wheelpath.

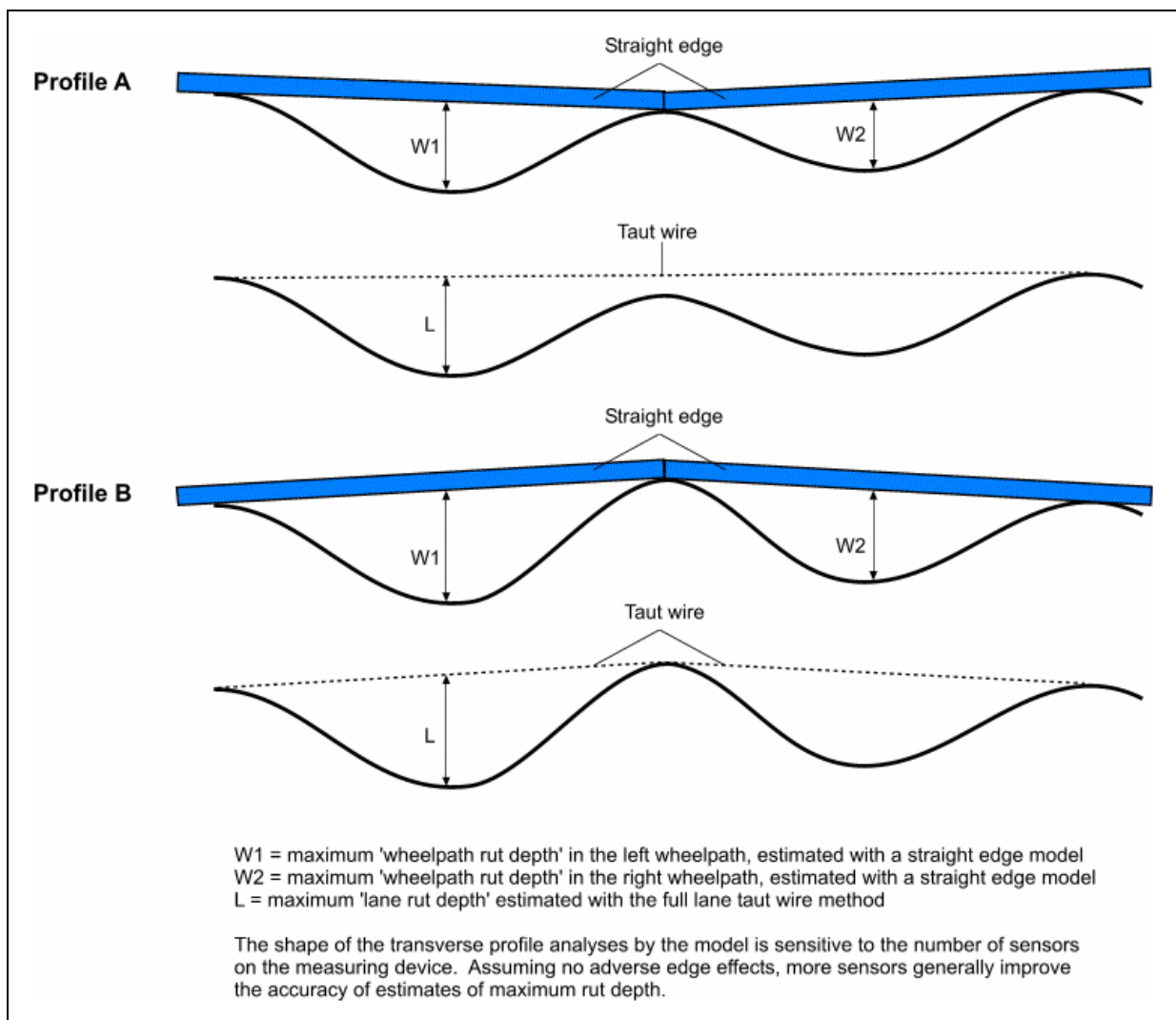


Figure 7.1: Straight edge and taut wire models for rut depth measurement

8 REPORTING

For each test run, the following data must be recorded but not necessarily reported:

- (a) survey title/contract number
- (b) date and time
- (c) survey device identification
- (d) operator
- (e) driver
- (f) road number/reference
- (g) road name (if applicable)
- (h) test direction
- (i) test lane
- (j) start and end references
- (k) intermediate features and/or reference points (if applicable)
- (l) any unusual occurrences (e.g. lane changes, bridge abutments, end of seal, etc.).

For each 100 m test result (or less, if required), the following data must be recorded:

- (a) wheelpath rut depth – for both the left and right wheelpaths (to the nearest 0.1 mm)
- (b) wheelpath standard deviation – for both the left and right wheelpaths (to the nearest 0.1 mm)
- (c) wheelpath rut bins, using the bins listed in 7.1(d) – for both the left and right wheelpaths (to the nearest 1 %)
- (d) vehicle speed during test
- (e) error or event flags
- (f) operator comments where applicable.

For each 100 m test result (or less, if required), the following optional additional data may be recorded:

- (a) lane rut depth (to the nearest 0.1 mm)
- (b) lane standard deviation (to the nearest 0.1 mm)
- (c) lane rut bins, using the bins listed in 7.1(d) (to the nearest 1%).

AUSTROADS TEST METHOD AG:AM/T009

PAVEMENT RUTTING MEASUREMENT WITH A MULTI-LASER PROFILOMETER

ANNEX 1 – LASER SAFETY

INTRODUCTION

Lasers used in road condition measurement systems can present a risk of injury if they are operated incorrectly.

This Annex outlines, in general terms only, some of the hazards and precautions relevant to the use of lasers in road condition measurement. This information has been included in order to raise awareness of issues. It does not override safety warnings/procedures specified by equipment suppliers or other relevant work practices, requirements or standards. Refer to AS2211:2004 (Standards Australia 2004) for further information.

The lasers used in profilometers are classified as Class 2, 3B and 3R lasers (Standards Australia, 2004) and may be visible (having a wavelength less than 700 nanometres (nm)) or invisible/infrared (wavelength greater than 700 nm).

PERSONNEL

Only trained personnel should operate laser equipment. Personnel unfamiliar with laser safety procedures must be kept away from operating lasers by verbal instruction or by use of warning signs, screens or other hazard warning devices.

RISKS

The extent of damage that lasers can cause to the eye or skin is dependent upon the duration of exposure. Due to its concentrated nature, laser light, whether visible or invisible, can cause damage to the eye before the eye can avoid exposure by blinking or looking away.

The major difference between exposure to the eye or skin is that the eye focuses the laser light onto the back of the eye.

There are two types of eye injury that can result from exposure to laser light:

- (a) Thermal injury – heat from the laser light causes a change in proteins in the eye, similar to the change in egg white that occurs when an egg is cooked; this damage may or may not be permanent.
- (b) Thermal-mechanical injury – heat from the laser light causes blood vessels in the eye to rupture; this damage cannot be repaired.

LASER IDENTIFICATION

Lasers are identified by a number of warning labels, including warning symbols, class identifiers, wavelength labels and aperture markers.

The laser aperture marker indicates the aperture through which the laser is emitted. Before testing, calibrating or using a laser system it is important to be aware of the location of all laser apertures.

Wavelength labels indicate the wavelength (nm) of the emitted laser light. Laser safety glasses and laser indicator cards must be selected to match the wavelength of the laser with which they will be used.

Laser indicator cards must be used when determining the direction of a laser beam. Cards used must be appropriate for the wavelength of the lasers. Safety glasses, suitable for the wavelength of the lasers, must be worn when using laser indicator cards.

JEWELLERY AND OTHER REFLECTIVE OBJECTS

It is important that reflective objects not be put in the path of an operating laser beam. When checking, testing or calibrating a laser all jewellery (watches, rings, etc.) must be removed from the hands and wrists.

CALIBRATION BLOCKS AND PLATES

Laser system manufacturers usually supply calibration blocks/plates with their equipment, and it is important that only these blocks/plates be used for calibration. The surface finish of these blocks is manufactured to provide a diffuse reflection of laser beams, reducing the risk of exposure to damaging levels of laser radiation.

AMENDMENT RECORD

Amendment No.	Sections amended	Action ⁽¹⁾	Date
1 (Initial release)	All (Richard Wix & Michael Moffatt, ARRB)	New	26 March 2007
2 (Revised release)	All (Richard Wix & Young Choi, ARRB, project AT1484)	Substitution	2 March 2011
¹ Key: Format change in format Substitution old section removed and replaced with new section New insertion of new section Removed old section removed			