AUSTROADS TEST METHOD AG:AM/T001

PAVEMENT ROUGHNESS MEASUREMENT WITH AN INERTIAL LASER PROFILOMETER

1 SCOPE

This test method defines the procedure for measuring the roughness of road pavements, determined from the direct measurement of the longitudinal profile of the road surface using a vehicle-mounted inertial laser based non-contact device (i.e. a laser profilometer).

Roughness collected using this test method is expressed in terms of the International Roughness Index (IRI). Conversion of IRI to equivalent NAASRA Roughness Meter (NRM) counts is included.

A single test measurement produced by this method is the average lane IRI of a 100 m length of road.

Inertial 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 rutting 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

ASTM E 1926-98 (2003). Standard practice for computing International Roughness Index of roads from longitudinal profile measurements.

Austroads Test Method AG:AM/T002. Pavement roughness validation checks for an inertial laser profilometer (reference device method). March 2007.

Austroads Test Method AG:AM/T003. Pavement roughness validation checks for an inertial laser profilometer (loop method). March 2007.

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

International Organization for Standardization (ISO) 1994, Quality management and quality assurance: vocabulary, ISO 8402, ISO, Geneva.

National Association of Australian State Road Authorities (NAASRA) (1981). Standard Operating Instructions for the NAASRA Roughness Meter and Guide for the Serviceability Rating of Road Pavements. Austroads Publication MEC-4. (Austroads: Sydney)

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

3 DEFINITIONS

(a) Longitudinal profile

Longitudinal profile is the shape of a pavement surface measured as vertical distances from a datum horizontal plane along the direction of traffic flow.

(b) Laser profilometer

A laser profilometer (or laser profiler) is a vehicle fitted with a laser-based measurement system that records the measured longitudinal road profile.

(c) International Roughness Index (IRI)

The IRI is a mathematical model of the dynamic response of a real vehicle travelling along a single wheelpath (or wheel track) of longitudinal road profile, referred to as the quarter-car (or World Bank) model. The IRI is expressed in terms of accumulated displacement of the simulated suspension in metres per measured kilometre (m/km). IRI can be reported in different ways, as follows:

- Single Track IRI

  The IRI based on a quarter-car model run at 80 km/h over a single wheelpath of longitudinal profile (ASTM E 1926-98 2003).

- Lane IRI

  This is a composite IRI value representing the roughness of a road lane section. It can be determined by two methods: profile averaging (also know as the half-car method); and Single Track IRI track averaging (quarter-car method). Both methods offer a good correlation with NAASRA Roughness Counts.

  With a goal of achieving consistency of practice among road agencies in Australasia, Austroads recommends use of the Single Track IRI track averaging (quarter-car) method, and it is this method that is used throughout this Test Method. Further explanation of these methods is provided in the Guide to Asset Management, Part 5B: Roughness.

  Using the Single Track IRI averaging (quarter-car) method, Lane IRI is determined by averaging two individual Single Track IRI values obtained separately in each wheelpath of a lane (at 0.75 m on either side of the centre of the lane mid-track).

(d) NAASRA Roughness Meter (NRM)

A standard mechanical device used extensively in Australian and New Zealand since the 1970s for measuring road roughness by recording the upward movement of the rear axle of a standard station wagon relative to the vehicle's body as the vehicle travels at a standard speed along the road being tested. A cumulative upward vertical movement of 15.2 mm corresponds to 1 NAASRA Roughness Count. Refer to NAASRA (1981) for further details.

For reporting purposes this test method allows for the determination of NAASRA Roughness Counts using the following relationship:

$$NAASRA\text{ (counts/km)} = 26.49 \times Lane\ IRI\text{ (m/km)} - 1.27$$

(e) 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.

(f) 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) An inertial laser profilometer consisting of the following:

- A vehicular platform capable of transporting testing equipment, mounting the profile measuring equipment and travelling at a range of speeds up to the limit of the operating range of the profile measuring equipment.
- Accelerometer(s) to establish the inertial reference which enables reference to be maintained at the level of resolution and accuracy required for the displacement measurement transducer(s).
- A displacement transducer (laser device) which measures the distance between the accelerometer and the travelled surface. The displacement transducer(s) shall be set to ensure mid-range operation during normal operation.

  Note: When measuring the profile of two wheelpaths simultaneously, a laser transducer/accelerometer combination shall be used for each wheelpath. The lateral distance between the displacement transducers to measure in the wheelpaths shall be 1.5 m (i.e. 0.75 m from the centreline of a lane).
- A distance measuring transducer capable of measuring the distance travelled to an accuracy of ±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 capturing the output data from the transducers at known equal intervals, not greater than 50 mm, within the range of wave lengths of 0.5 m and 50 m.

- A processing computer to analyse the profile data, and by applying the ‘quarter car’ model obtain IRI for a single wheelpath and Lane IRI.

(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 by driving the host vehicle over a known distance (1 km to an accuracy of ± 1 m) and recording the number of pulses or ticks produced by the transducer.

(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 Accelerometers

Calibration and checking of the accelerometers must be undertaken in accordance with the manufacturer’s requirements and procedures (refer manufacturer’s User Manual).

5.1.3 Laser displacement transducers

(a) The laser displacement transducers must be calibrated using the gauge blocks and flat plates 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 must be carried out in accordance with Austroads Test Method AG:AM/T002 or Test Method AG:AM/T003.

(b) 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 setup

(a) Tyres shall be maintained at the manufacturer's recommended tyre pressure.

(b) All testing equipment and cables must be correctly mounted, connected and secure, as per the manufacturer's User Manual.

(c) 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.

(d) Ensure that the serial numbers (or other information that allows traceability to calibration documentation) are recorded for all sensors.

(e) Perform manufacturer's operational validation procedure ('bounce test') (refer 6.2, and manufacturer's User Manual).

(f) Ensure that all appropriate warning devices and equipment are in place and operational.

6.2 Operational validation procedure ('bounce test')

(a) A manufacturer's operational validation test (commonly known as a 'bounce 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, the accelerometers and their associated electronics. The test simulates a bouncing vehicle travelling along a completely flat surface. The measured profile should be zero, as movement of the vehicle is expected to be cancelled out by the accelerometers. However, due to electronic noise and other factors a negligible roughness value is usually recorded, i.e. less than 0.15 m/km.

(c) A base plate used for transducer calibrations (refer 5.1.3) should be used when performing a bounce test so as to minimise any roughness measurements that may be obtained due to surface unevenness.

(d) Throughout the 'bounce test', roughness readings greater than 0.15 m/km are unacceptable, and survey testing must not commence until the causes for the high reading have been identified and corrected.

6.3 Profile survey

(a) The operator shall follow manufacturer's instructions for 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) Ensure the vehicle is travelling within the manufacturer's operational speed range prior to the defined start point of the survey.

(e) 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.

(f) 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.

(g) Following the instructions in the manufacturer's User Manual, measure the surface profile along 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.

(h) Testing must be terminated if conditions are such that difficulty is encountered maintaining the required test lane and/or minimum test speed.

(i) No attempt should be made to avoid pavement defects unless they are likely to damage the vehicle and/or jeopardise safety.

(j) 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 (see 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 roughness 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
- 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.

7 CALCULATIONS

Calculate the following:

(a) the single track IRI_{qc} using the quarter car model for each wheelpath for each 100 m section being tested

(b) the lane IRI for each lane for each 100 m section being tested is as follows:

$$Lane\ IRI_{qc} = \frac{IRI_{qc\,L} + IRI_{qc\,R}}{2}$$

where

$Lane_{qc}\ IRI = \text{Lane Roughness (IRI m/km)}$

$IRI_{qc\,L} = \text{Roughness of left wheel path profile (IRI m/km)}$

$IRI_{qc\,R} = \text{Roughness of right wheel path profile (IRI m/km)}$

The lane IRI for each 100 m section represents a test result

(c) if required, the NAASRA roughness for each lane for each 100 m section being tested using the following equation:

$$NAASRA\ \text{(counts/km)} = 26.49 \times Lane\ IRI_{qc}\ \text{(m/km)} - 1.27$$

8 REPORTING

For each test run, the following data must be recorded:

(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:

(m) left wheelpath IRI_{qc} (to the nearest 0.01 m/km)

(n) right wheelpath IRI_{qc} (to the nearest 0.01 m/km)

(o) lane IRI_{qc} (to the nearest 0.01 m/km)

(p) NAASRA Roughness Count, if required (to the nearest whole number)

(q) vehicle speed during test

(r) error or event flags

(s) operator comments where applicable.

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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 3B lasers (Standards Australia, 2004) and may be visible (having a wavelength less than 700 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 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 (Michael Moffatt, ARRB)	New	26 March 2007

[1] Key:

Format	change in format
Substitution	old section removed and replaced with new section
New	insertion of new section
Removed	old section removed