Test method T187

Measurement of ride quality of road pavements by laser profiler

OCTOBER 2012

Revision Summary

Ed/Rev Number	Clause Number	Description of Revision	Authorisation	Date
		Reformatted and Revision Summary Added	D.Dash	May 1999
		Date on Test Method Revised to Agree with Date on Revision	D.Dash	Feb 2001
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Ed 2/ Rev 0	All	Reformatted RMS template	J Friedrich	October 2012

Note that Roads and Maritime Services is hereafter referred to as 'RMS'.

The most recent revision to Test method T187 (other than minor editorial changes) are indicated by a vertical line in the margin as shown here.

Test method T187

Measurement of ride quality of road pavements by laser profiler

1. Scope

This test method defines the procedure for measuring ride quality, of road pavements, determined from the direct measurement of the longitudinal profile of the road surface using a vehicle mounted laser based non-contact device. This instrument will subsequently be referred to as a Laser Profiler in this document.

NOTE: This test method is not suitable for application on unsealed roads.

2. General

Term	Definition
Term	
Laser Profiler	(a) A vehicle fitted with a laser-based measurement system that records the measured longitudinal road profile.
Road profiles	(a) Are considered as being made up of a large number of sinusoids of varying wavelengths and amplitudes. The wavelength values range for roughness is 0.5 m to 50 m (PIARC). The roughness test result is a measure of the riding quality of pavement surfaces in response to that longitudinal profile. Roughness, as determined by the Laser Pofiler, is reported in 100 m intervals in dimensionless units as International Roughness Index (IRI, m/km). By using the equations provided it can be converted to NAASRA Roughness Meter Counts (NRM Counts/km). To capture the features of these sinusoids over the wavelengths of interest, the sampling interval should be no greater than half the shortest wavelengths of interest, or 250 mm.
International Roughness Index	(a) a mathematical model of the dynamic response of a real vehicle along a single track (or wheelpath) of longitudinal road profile, referred to as the quarter-car (World Bank) model. The IRI is expressed in terms of accumulated displacement of the simulated suspension in metres per measured kilometre (m/km) NAASRA (counts/km) = 26.49 x Lane IRI_{qc} (m/km) – 1.27 Where qc = quarter-car model (b) More consistent correlation is obtained between IRI and the NAASRA Roughness Meter measurements where IRI is computed using the average of the two wheelpath profiles i.e. the half-car simulation (Prem 1989a). (c) The relationship between the International Roughness Index and NAASRA Roughness counts/km can be demonstrated by: NAASRA (counts/km) = 33.67 x Lane IRI_{hc} (m/km) – 1.95 Where hc = half-car model (d) One NAASRA Roughness count is defined as a 15.2mm upward displacement of a Response Type Road Roughness Measuring System (RTRRMS) vehicle's body with reference to the differential of the vehicle (Test method T182).

3. Apparatus

(a) Vehicular platform

(b) Laser-based non-contact displacement transducers for vertical distance measurement to the road surface

(c) Accelerometers for vertical acceleration measurement

(d) Horizontal linear distance measurement device, accurate to ± 0.1 %

(e) Data acquisition hardware and software to facilitate data capture and real time interaction with the operator

(f) Manufacturer's User Manual

(g) Displacement transducers calibration equipment (flat plates and gauge blocks)

(h) Appropriate warning devices such as magnetic signs and flashing light

4. Procedure

4.1 Pre-Test Setup

(a) Tyres shall be maintained at the manufacturers recommended tyre pressure

(b) All testing apparatus 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 beam is refitted to the vehicle.

(d) Perform manufacturer's operational verification procedure ('bounce test') see Clause 6.3 Operational Verification Procedure

(e) Ensure that all warning devices are in place and operational

4.2 Driving

4.2.1. Speed

(a) The test speed shall be governed by the manufacturer's operational speed range for the equipment, legal speed limits and road and traffic conditions encountered

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

4.2.2. Technique

(a) Overtaking is permitted only where essential to maintain vehicle speed within the test range and provided that each lane is of similar roughness so that no significant error will arise

(b) All such events that may influence roughness measurements must be noted and/or flagged

(c) The vehicle must be driven in the usually trafficked wheel paths

4.2.3. Road Surface Conditions

(a) No attempt must be made to avoid pavement defects unless they're likely to damage the vehicle and/or jeopardise safety

(b) 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 and results for the section discarded. Arrangements shall be made to test the section when weather conditions are more favourable, if required

(c) If localised areas of contamination of the road surface are encountered (e.g. mud, debris etc) this must be noted and/or flagged and results for the section discarded. Arrangements shall be made to test the section when surface conditions are more favourable, if required

(d) Road features that lie beyond the range of the vertical displacement transducers, e.g. gaps in bridge abutments, must be noted and/or flagged and results for that section discarded

4.2.4. Test Lane

During routine surveys, the lane tested must be that used by the majority of traffic, generally the slow (kerb) lane in a multi lane situation. The median lane shall be tested if parked vehicles obstruct the kerb lane; this must be noted on the report. Where specifically required, testing may be conducted on other lane(s) as required and reported accordingly

4.3 Recording of data

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

(a) Survey Title / Contract Number

(b) Date

(c) Road number (e.g. MR184, SH10, etc)

(d) Road name if applicable

(e) Test Direction

(f) Lane tested (As per RMS's convention)

(g) Start and End references. If ROADLOC system is being used ROADLOC references (CP or RP) are to be used

(h) Intermediate features and/or ROADLOC references if applicable

(i) Any unusual occurrences (e.g. lane change, bridge abutments, end of seal, etc)

For each 100 metre interval:

(a) Left IRI

(b) Right IRI

(c) Lane IRI

(d) NAASRA Roughness Count

(e) Speed (If recorded)

(f) Lane

(g) Error or event flags

(h) Operator comments where applicable

4.4 Reference Points

(a) Where applicable, data must be collected with reference to the Road Authority's 'ROADLOC' system. Note that, to avoid the accumulation of distance recording errors RTA requires that the distance measurement is re-zeroed at each of it's ROADLOC Control Points during Network Survey Operation.

(b) Provision must also be made for a generic data collection mode to be used for jobs where no road referencing system exists (eg. construction sites, runways, etc).

4.5 Ride Quality – Pavement Construction - Audit Surveys

4.5.1 Procedure

This section describes the procedure to be followed when carrying out audit surveys of newly constructed, or rehabilitated, road sections. It also applies to the auditing of Network testing.

Survey lengths will be specified in the job requests, but in any event must be in multiples of 100 metres with an allowance at each end of the test section for the "lead in and lead out" distances required for the operation of the Profiler, as follows:

(a) Ensure that the vehicle's test speed is within the manufacturer's operational speed range prior to entering the audit section to be tested.

(b) Whenever possible, do not start/end survey at Seal changes or bridge abutments as they would influence the roughness results for that particular section.

(c) Measure the surface profile along each wheelpath with the centre of the vehicle coinciding with the centre of the lane being surveyed.

(d) Record any unusual features that might influence the results.

(e) Steps (b) and (c) must be repeated 2 more times, a minimum of 3 sets of results is required for audit testing.

(f) Steps (b) and (c) must be repeated 4 more times for Network Audit testing or if requested.

4.5.2. Quality Audit Reporting

(a) Lane IRI and NAASRA Roughness counts per kilometre must be reported, using the appropriate conversion models, as whole numbers.

(b) The average of the Lane IRI values and NAASRA Roughness values for each 100 metre section is to be reported.

(c) Any intervals less than 100 metres in length are to be omitted from the report.

(d) Features that would influence the results such as bridge abutments, seal changes, speed humps, cattle grids, steel plates, etc, are to be omitted from the calculations whenever possible.

(e) See Appendix A for the procedure on the analysis of data.

5. Calibration

5.1 Component Calibration and Installation

5.1.1. Distance Transducer

(a) The Data Acquisition System must record the linear distance travelled by the vehicle during testing, by a distance transducer fitted to the host vehicle, to an accuracy of ± 0.1%.

(b) This device normally takes the form of a shaft encoder mounted onto one of the host vehicle's driver side wheels.

(c) The distance transducer must be calibrated by driving the host vehicle over a known distance (one kilometre to an accuracy of ± 1.0 metre) and recording the number of pulses or ticks produced by the transducer. Knowing the number of pulses produced over a standard distance, a calibration factor is then calculated relating the number of pulses to the distance travelled.

(d) The calibration factor and associated information such as date and time of calibration is then stored and used for all subsequent testing until such time as a new distance calibration is performed.

(e) Distance calibrations must be performed whenever the distance transducer is fitted back on the vehicle and immediately following any change to the distance transducer or a change to any part of the host vehicle that may interfere with the existing calibration constant.

5.1.2. Accelerometers

Calibration and checking of the accelerometers must be undertaken in accordance with the manufacturers' requirements and procedures, see manufacturer's User Manual.

5.1.3. Laser Displacement Transducers

(a) The vertical displacement transducers have a finite range over which they can operate, it is important that when they are mounted in their normal operating position, they are at or near the mid-point of their working range.

(b) Vertical displacement transducers must be calibrated immediately following any change to the laser transducers or a change to any part of the host vehicle, such as wheels or tyres, that may interfere with the existing calibration constant.

(c) Vertical displacement transducer must be calibrated using the step gauge blocks and the flat plates in accordance with the manufacturer's requirements, for details refer to the manufacturer's User Manual.

(d) The tolerances on all dimensions of the gauge block must be within ± 0.2 mm.

(e) The scale factor is acceptable if the measured values fall within ± 0.5 mm of the gauge block dimensions

(f) It is recommended that the gauge block is 25mm x 50mm x 100mm in size, and that the gauge block and base plate have non-reflective surfaces to avoid the possibility of reflecting the laser beam from the transducers into the eyes of the operators whilst performing the calibrations or checks. See Appendix B for Laser Safety procedures.

5.2 Validation

5.2.1. Laser Profiler Correlations

A system validation must be carried out at least once a year. A sound and stable site that represents different types of surfaces, as well as a wide range of roughness values, is required for this purpose. See Appendix A for procedure.

6. Procedures

6.1 Reporting

(a) Roughness data must be reported in IRI and converted to NAASRA Roughness counts per kilometre, using the appropriate conversion models, as whole numbers.

(b) Test interval for reporting is 100 metres. Final test intervals of less than 50 metres are to be omitted from the report. If required, the final test interval can be weighted into the last whole 100 metre interval.

(c) Reports must include test and location data as specified in Clause 4.3, Recording of Data

6.2. Calibration Procedure

Refer to Clause 5. Calibration and Manufacturers' User Manual.

6.3. Operational verification procedure (Bounce test)

(a) A manufacturer's operational verification (bounce) test must be performed before the start of each days testing. See Manufacturer's User Manual.

(b) This test verifies the correct operation of the laser displacement transducers, the accelerometers and their associated electronics. Essentially this test simulates a vehicle travelling along a surface with zero unevenness; theoretically, the measured profile would be zero, as any movement of the vehicle will be cancelled out by the accelerometers, however, due to electronic noise and other factors a negligible roughness value, ie. less that 5 NAASRA counts/km, is accepted.

(c) The flat plates used for transducer calibrations, see section 5, should be used when performing a bounce test so as to minimise any roughness measurements that may be obtained due to surface unevenness.

(d) If the laser transducers, accelerometers or any of their associated electronics are malfunctioning, the processed results will show a higher than normal reading for the roughness values. Testing must not commence until the fault has been identified and corrected.

APPENDIX A

PROCEDURE FOR PROFILER VERIFICATION

Purpose

This procedure was developed by RMS NSW and has been used by a number of Australian road organisations to accredit Profilers for project and network level roughness surveys. Use of the procedure has been specifically confined to a well documented 32 km long "Roughness Calibration Loop" located approximately 60 km north of Sydney.

- This procedure is designed to:
- Ensure the calibration of the profiler (including the host vehicle and installed instruments);
- Assess the ability of the driver to track consistently; and
- Assess the ability of the operator to accurately correlate road condition data with physical location on the road.

Background

The RMS's "Roughness Calibration Loop" consists of two separate sites in close proximity, one on an old but sound and stable section of the Pacific Highway, now mainly used for local access, and the other on the Sydney/Newcastle Freeway which is a road that is generally maintained to a relatively high standard.

This procedure involves comparison of roughness data from the proposed operational device against a reference set of roughness data.

The reference roughness dataset is obtained by averaging the results (based on 100 m sections) of five repeat runs by the RMS's Laser Profilometer (the reference device). RMS conducts regular repeat runs with the reference device to ensure that the reference data remains valid.

Procedure

For a verification test, each proposed operational roughness measuring device is required to carry out five repeat runs with each crew (driver and operator), a total survey distance of approximately 161 km. Using control points in RMS's location system (ROADLOC), the roughness data is split into links varying in length from 0.415 km to 6.060 km. RMS Pavements Branch then excludes data for sections shorter than 100 m, calculates the average roughness value for each 100 m section, and conducts the analysis.

Analysis

The analysis consists of two stages. For accreditation, a pass is necessary at both stages.

The first stage consists of regression analysis to test the r^2 correlation for the average roughness value for each 100 m section from the proposed operational device against the RMS's reference data. For a pass, this r^2 correlation should be at least 0.95.

In the second stage, the "Average Percentage Difference" is calculated. "Average Percentage Difference" is the overall average of the percentage differences for each 100 m section, between the average of the five runs of the proposed operational device and the corresponding reference data. It is obtained using the following equation:

$$\textit{Average Percentage Difference} = \frac{\sum_{1}^{n} \frac{(A_n - B_n)}{B_n} \times 100}{n}$$

Where

A_n = Average of five readings of roughness of n^{th} 100 m section, obtained by the proposed operational roughness measuring device;

B_n = RMS reference roughness value for n^{th} 100 m section; and

n = Total number of 100 m sections in analysis.

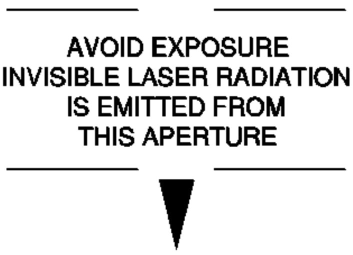
For a pass, the "Average Percentage Difference" must be not greater than +/- 5%.

Provided a pass is achieved on both criteria, RMS issues an accreditation certificate showing the r^2 correlation results and the "Average Percentage Difference" for the specific vehicle/crew combination. The accreditation certificate remains current for a period of 12 months, and is conditional on any subsequent repairs to the vehicle's installed instruments automatically invalidating any accreditation(s) performed prior to the repairs being carried out.

APPENDIX B

LASER SAFETY

The lasers used in most systems are Class 3B devices which emit **<u>INVISIBLE</u>** radiation in a small focussed beam. Under no circumstances should any person look directly into the laser aperture ***<u>or view any reflected beam from a polished or mirror surface</u>***, as this can cause permanent eye damage.



The presence of the beam can only be seen by observing its effect on a special card.

Warning labels (yellow background/black text) indicating the presence of a class 3B laser hazard must be affixed to the laser housings.

In accordance with AS 2211-1991, lasers must be fitted with a mechanical shutter which must be set to cover the laser apertures (small diameter aperture) when the system is energised during periods of maintenance or vehicle repairs etc.

No person shall be permitted to get under the vehicle unless the trained personnel have first verified that:—

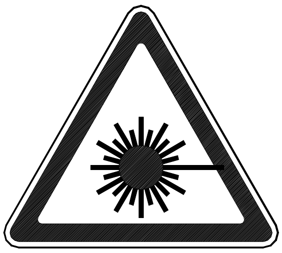
(a) The lasers are switched off.

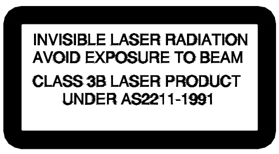
(b) The laser shutters are all in the closed position.

This must be enforced for any access by persons not trained in the systems, including vehicle service personnel.

For any work involving lens cleaning, where it is necessary to open the mechanical shutter, then steps (a) and (b) shall first be verified in that order, followed by:—

(c) Approved laser safety glasses must be worn.





(d) Each laser shutter is opened and cleaned in turn.

(e) The person cleaning the lens should also verify that the laser is not operating by first conducting a check with the laser card. The card should be held under the aperture and the absence of the red spot confirmed.

NOTE: Only after steps a, b, c, d, and e have been performed and confirmed, should an authorised person look directly into the aperture, and then <u>only</u> <u>if</u> <u>absolutely</u> <u>necessary</u>. Generally, all inspections should be conducted by conducting steps a through e and only then viewing the apertures (during cleaning or replacement) from an angle – not directly.

WARNING: Under no circumstances shall any person be permitted to look into the laser apertures without the approved eye protection spectacles having the correct spectral characteristics for these lasers.