

# AUSTROADS TEST METHOD AG:AM/T004

## PAVEMENT ROUGHNESS REPEATABILITY AND BIAS CHECKS FOR AN INERTIAL LASER PROFILOMETER

### 1 SCOPE

This test method defines the procedure for conducting repeatability and bias of measurement checks for a vehicle-mounted, road roughness measuring device.

The bias check included in this method is used to determine whether there is a systematic drift in a profilometer's measurements over time. It does not cover the collection of reference data from a separate measurement device.

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.

### 2 REFERENCED DOCUMENTS

Austrroads Test Method AG:AM/T001. Pavement roughness measurement with an inertial laser profilometer. March 2007.

### 3 DEFINITIONS

- (a) Measurement repeatability: an indication of variation in measures about the mean.
- (b) Bias error: an indication of whether a device is systematically measuring high or low when compared to a reference set of measures.

### 4 EQUIPMENT

The following equipment is required:

- (a) A calibrated inertial laser profilometer as detailed in Austrroads Test Method AG:AM/T001.

### 5 PROCEDURE

#### 5.1 Repeatability checks

- (a) Select a clearly defined section of a lane of 10 km total length with a range of roughness at the 100 m segment level.
- (b) Following Test Method AG:AM/T001, use the profilometer to measure the single track IRI in both the left and right wheelpaths, and determine the average lane IRI.

- (c) Repeat (b) until five sets of profile measurements have been taken.

## 5.2 Bias error check

- (a) Select a clearly defined section of a lane of 10 km total length with a range of roughness at the 100 m segment level.
- (b) Following Test Method AG:AM/T001, use the profilometer to measure the single track IRI in both the left and right wheelpaths, and determine the average lane IRI. This data forms the reference data.
- (c) Repeat (b) at a later specified time, to produce the comparison data.

# 6 CALCULATIONS

## 6.1 Repeatability checks

An example of these repeatability checks can be found in Annex 1 to this Test Method.

### 6.1.1 Repeatability Requirement 1

Determine the coefficient of variation (i.e. the standard deviation expressed as a percentage of the mean),  $S_n\%$ , for each 100 m segment for each series of repeat measurements as follows:

$$S_n\% = 100 \cdot \frac{S_n}{\bar{X}_n}$$

where

$$S_n = \sqrt{\frac{\sum_{i=1}^N (X_{ni} - \bar{X}_n)^2}{N-1}}$$

$$\bar{X}_n = \frac{\sum_{i=1}^N X_{ni}}{N}$$

$n$  = segment number

$N$  = total number of measurements on segment  $n$

$X_{ni}$  = roughness of segment  $n$  from measurement  $i$  (with  $i = 1$  to  $N$ )

### 6.1.2 Repeatability Requirement 2

Determine the average of the segment coefficients of variation,  $\bar{S}\%$ , as follows:

$$\bar{S}\% = \frac{\sum_{n=1}^{n_s} S_n\%}{n_s}$$

where

$n_s$  = total number of segments

### 6.1.3 Repeatability Requirement 3

Using least squares regression, determine the coefficient of determination,  $r^2$ , when the individual roughness values for each segment (dependent variable,  $y$ ) are regressed against the mean values for that segment (independent variable,  $x$ ).

## 6.2 Bias error check

Calculate the bias error between the comparison data set and the reference data set as follows:

$$BE = \left| \frac{100}{n} \cdot \sum_{i=1}^n \left( \frac{\bar{X}_{Ri} - \bar{X}_{Ci}}{\bar{X}_{Ri}} \right) \right|$$

where

$BE$  = the bias error between the comparison and reference data sets

$\bar{X}_{Ri}$  = reference data mean roughness of segment  $i$

$\bar{X}_{Ci}$  = comparison data mean roughness of segment  $i$

$n$  = total number of segments

# 7 REPORTING

## 7.1 General details

Report the following:

- (a) the location of each test section
- (b) date and time of validation checks
- (c) identification of laser profilometer and base instruments used
- (d) operator and driver of the profilometer system and vehicle.

## 7.2 Repeatability checks

Report the following:

- (a) the IRI for each 100 m section for each of the five repeat runs
- (b) the coefficient of variation for each 100 m segment for each series of repeat measurements as determined in 6.1.1
- (c) the average of the segment coefficients of variation as determined in 6.1.2
- (d) the coefficient of determination when the individual roughness values for each segment are regressed against the mean values for that segment, as determined in 6.1.3
- (e) a statement as to whether Repeatability Requirement 1 has been passed – pass is achieved when 95% of all values reported in (b) are less than or equal to 5%
- (f) a statement as to whether Repeatability Requirement 2 has been passed – a pass is achieved when the value reported in (c) is less than or equal to 3%
- (g) a statement as to whether Repeatability Requirement 3 has been passed – a pass is achieved when all values reported in (d) are equal to or greater than 0.95.

### **7.3 Bias error check**

Report the following:

- (a) the reference data set IRI for each 100 m section
- (b) the comparison data set IRI for each 100 m section
- (c) the bias error determined in 6.2
- (d) a statement as to whether the bias error check is passed – a pass is achieved when the bias error is  $\leq 1\%$ .

## **8 FAILED REPEATABILITY AND/OR BIAS ERROR CHECKS**

In the event that the profilometer fails the repeatability and/or bias error checks, causes for the failure must be investigated, defects rectified and this test method repeated.

## **AUSTROADS TEST METHOD AG:AM/T004**

# **PAVEMENT ROUGHNESS REPEATABILITY AND BIAS CHECKS FOR AN INERTIAL LASER PROFILOMETER**

## **ANNEX 1 – EXAMPLE OF REPEATABILITY AND BIAS CHECKS**

### **Repeatability example**

Using data from an arterial road in Australia in 1998, Table 1 illustrates the three repeatability check requirements outlined in this Test Method.

It should be noted that the Test Method requires that a test section 10 km long be used in undertaking these repeatability checks. The data shown in Table 1 represents a total length of only 3.2 km. (The truncated data is used here only to ensure that the Table fits within a single page of this document.)

The data in Table 1 shows five repeat runs along the test section, and reports the IRI roughness of each 100 m segment.

It can be seen from the Table that Repeatability Requirement 1 has not been passed, as less than 95% of the coefficients of variation between the individual survey runs and the mean of the runs (the far right column in the Table) are  $\leq 5\%$ .

Repeatability Requirement 2 has been successfully met, with the average of all segments coefficient of variation being  $\leq 3\%$ .

Finally, Repeatability Requirement 3 has also been passed, with the  $r^2$  value for the regression relationship between the segment IRI values for each run versus the means of all runs being at least 0.85 for all runs.

### **Bias error example**

Using data from an arterial road in Australia in 1998, Table 2 illustrates the calculation of bias error. As the calculated bias error is less than 1%, the test data represents a pass.

It should be noted that the Test Method requires that a test section 10 km long be used in undertaking a bias error check, whereas the data shown in Table 2 represents a total length of only 3.2 km. (The truncated data is used here only to ensure that the Table fits within a single page of this document.)

Table 1: Example of roughness repeatability checks

Data point (Chainage)	Run 1 (IRI)	Run 2 (IRI)	Run 3 (IRI)	Run 4 (IRI)	Run 5 (IRI)	Mean (IRI)	Standard deviation	Coefficient of variation (%) Repeatability Requirement 1	
5,200	2.84	2.99	2.92	2.99	3.14	2.98	0.11	✓	4%
5,300	3.03	3.07	2.99	3.03	3.07	3.04	0.03	✓	1%
5,400	4.01	4.09	3.97	4.16	3.75	4.00	0.16	✓	4%
5,500	4.80	4.77	4.65	5.03	4.62	4.77	0.16	✓	3%
5,600	5.11	4.62	5.11	4.88	4.96	4.94	0.20	✓	4%
5,700	5.22	4.99	4.96	5.45	5.56	5.24	0.27	✓	5%
5,800	5.67	5.18	5.30	5.52	5.56	5.45	0.20	✓	4%
5,900	4.28	4.05	4.05	3.79	3.71	3.98	0.23	✗	6%
6,000	1.90	1.67	1.97	1.71	1.75	1.80	0.13	✗	7%
6,100	1.48	1.52	1.52	1.48	1.48	1.50	0.02	✓	1%
6,200	1.71	1.75	1.63	1.71	1.71	1.70	0.04	✓	3%
6,300	2.80	2.88	2.77	2.95	2.95	2.87	0.08	✓	3%
6,400	2.01	1.94	2.05	1.94	1.90	1.97	0.06	✓	3%
6,500	1.82	1.90	1.94	1.90	1.97	1.91	0.06	✓	3%
6,600	1.71	1.75	1.67	1.67	1.67	1.69	0.04	✓	2%
6,700	1.71	1.75	1.71	1.67	1.71	1.71	0.03	✓	2%
6,800	3.11	3.03	3.03	2.92	2.99	3.02	0.07	✓	2%
6,900	3.03	2.80	2.95	2.88	2.92	2.92	0.09	✓	3%
7,000	1.78	1.90	1.82	1.86	1.90	1.85	0.05	✓	3%
7,100	1.78	1.90	1.90	1.86	1.86	1.86	0.05	✓	3%
7,200	1.71	1.75	1.75	1.78	1.78	1.75	0.03	✓	2%
7,300	1.10	1.07	1.07	1.07	1.07	1.08	0.01	✓	1%
7,400	0.99	0.99	0.99	1.07	1.03	1.01	0.04	✓	4%
7,500	2.28	2.24	2.28	2.31	2.31	2.28	0.03	✓	1%
7,600	2.54	2.46	2.54	2.35	2.50	2.48	0.08	✓	3%
7,700	2.54	2.50	2.58	2.50	2.61	2.55	0.05	✓	2%
7,800	1.78	1.78	1.75	1.78	1.78	1.77	0.01	✓	1%
7,900	5.18	5.26	5.26	5.14	5.33	5.23	0.07	✓	1%
8,000	1.75	1.75	1.71	1.71	1.71	1.73	0.02	✓	1%
8,100	2.35	2.35	2.43	2.39	2.39	2.38	0.03	✓	1%
8,200	1.63	1.67	1.67	1.67	1.63	1.65	0.02	✓	1%
8,300	2.28	2.24	2.43	2.50	1.90	2.27	0.23	✗	10%

Mean	2.69	2.64	2.67	2.68	2.66	2.67	0.08	✓	3%
r	0.9980	0.9978	0.9977	0.9974	0.9956	Repeatability Requirement 3			
r <sup>2</sup>	✓ 0.9960	✓ 0.9955	✓ 0.9954	✓ 0.9948	✓ 0.9912				
Slope	1.0277	0.9635	0.9787	1.0168	1.0132				
Intercept	-0.0561	0.0739	0.0571	-0.0352	-0.0397	Repeatability Requirement 2			

**Note:** Data and analysis are shown here for a length of only 3.2 km comprising 32 segments each 100 m long. This is to fit the Table on one page. However, in accordance with this test method, repeatability checks should be conducted over a length of 10 km.

Table 2: Example of roughness bias error check

Data point (Chainage)	Reference (IRI)	Comparison (IRI)	Calculations	
	$\bar{X}_{Ri}$	$\bar{X}_{Ci}$	$\bar{X}_{Ri} - \bar{X}_{Ci}$	$\frac{\bar{X}_{Ri} - \bar{X}_{Ci}}{\bar{X}_{Ri}}$
5,200	2.99	2.92	0.07	0.023
5,300	3.07	2.99	0.08	0.026
5,400	4.09	3.97	0.12	0.029
5,500	4.77	4.65	0.12	0.025
5,600	4.62	5.11	-0.49	-0.106
5,700	4.99	4.96	0.03	0.006
5,800	5.18	5.3	-0.12	-0.023
5,900	4.05	4.05	0.00	0.000
6,000	1.67	1.97	-0.30	-0.180
6,100	1.52	1.52	0.00	0.000
6,200	1.75	1.63	0.12	0.069
6,300	2.88	2.77	0.11	0.038
6,400	1.94	2.05	-0.11	-0.057
6,500	1.9	1.94	-0.04	-0.021
6,600	1.75	1.67	0.08	0.046
6,700	1.75	1.71	0.04	0.023
6,800	3.03	3.03	0.00	0.000
6,900	2.8	2.95	-0.15	-0.054
7,000	1.9	1.82	0.08	0.042
7,100	1.9	1.9	0.00	0.000
7,200	1.75	1.75	0.00	0.000
7,300	1.07	1.07	0.00	0.000
7,400	0.99	0.99	0.00	0.000
7,500	2.24	2.28	-0.04	-0.018
7,600	2.46	2.54	-0.08	-0.033
7,700	2.5	2.58	-0.08	-0.032
7,800	1.78	1.75	0.03	0.017
7,900	5.26	5.26	0.00	0.000
8,000	1.75	1.71	0.04	0.023
8,100	2.35	2.43	-0.08	-0.034
8,200	1.67	1.67	0.00	0.000
8,300	2.24	2.43	-0.19	-0.085

$$\sum_{i=1}^{32} \left( \frac{\bar{X}_{Ri} - \bar{X}_{Ci}}{\bar{X}_{Ri}} \right) = -0.274$$

$$\text{Bias error} = \left| \frac{100}{32} \cdot \sum_{i=1}^{32} \left( \frac{\bar{X}_{Ri} - \bar{X}_{Ci}}{\bar{X}_{Ri}} \right) \right| = 0.86\% \checkmark$$

**Note:** Data and analysis are shown here for a length of only 3.2 km comprising 32 segments each 100 m long. This is to fit the Table on one page. However, in accordance with this test method, repeatability checks should be conducted over a length of 10 km.

## AMENDMENT RECORD

Amendment No.	Sections amended	Action <sup>1</sup>	Date
1 (Initial release)	All (Michael Moffatt, ARRB)	New	26 March 2007
<sup>1</sup> Key: Format            change in format Substitution     old section removed and replaced with new section New                insertion of new section Removed          old section removed			