

AUSTROADS TEST METHOD AG:AM/T016

PAVEMENT SURFACE TEXTURE REPEATABILITY AND BIAS CHECKS FOR A LASER PROFILOMETER

1 SCOPE

This test method defines the procedure for conducting repeatability and bias of measurement checks for a vehicle-mounted, pavement surface texture 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/T013. Pavement surface texture measurement with a 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 laser profilometer as detailed in Austrroads Test Method AG:AM/T013.

5 PROCEDURE

5.1 Repeatability checks

- (a) Select a clearly defined section of a lane of 10 km total length with a range of surface texture at the 100 m segment level.
- (b) Following Test Method AG:AM/T013, use the profilometer to measure the surface texture in the left wheelpath and between wheelpaths.

- (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 surface texture at the 100 m segment level.
- (b) Following Test Method AG:AM/T013, use the profilometer to measure the surface texture in the left wheelpath and between wheelpaths. 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} = texture 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 texture 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 texture depth of segment i

\bar{X}_{Ci} = comparison data mean texture depth 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 surface texture for each 100 m section for each of the five repeat runs
- (b) the standard deviation for each 100 m segment for each series of repeat measurements as determined in 6.1.1
- (c) the coefficient of variation for each 100 m segment for each series of repeat measurements as determined in 6.1.1
- (d) the average of the standard deviations as determined in 6.1.2
- (e) the average of the segment coefficients of variation as determined in 6.1.2
- (f) the coefficient of determination when the individual surface texture values for each segment are regressed against the mean values for that segment, as determined in 6.1.3
- (g) a statement as to whether Repeatability Requirement 1 has been passed – a pass is achieved when 95% of all values reported in (b) are less than or equal to 0.15 mm or all values reported in (c) are less than or equal to 10%

- (h) a statement as to whether Repeatability Requirement 2 has been passed – a pass is achieved when the value reported in (d) is less than or equal to 0.1 mm or the value reported in (e) is less than or equal to 5%
- (i) a statement as to whether Repeatability Requirement 3 has been passed – a pass is achieved when all values reported in (f) are equal to or greater than 0.95.

7.3 Bias error check

Report the following:

- (a) the reference data set surface texture for each 100 m section
- (b) the comparison data set surface texture 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 $\leq 5\%$.

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.

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ANNEX 1 – EXAMPLE OF REPEATABILITY AND BIAS CHECKS

Repeatability example

Table 1, using data from a highway in Australia in 2006, 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 outer wheelpath texture 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 surface texture in the outer wheelpath of each 100 m segment.

It can be seen from the Table that Repeatability Requirement 1 has been passed, as more 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 $\leq 10\%$.

Repeatability Requirement 2 has been successfully met, with the average of all segments coefficient of variation being $\leq 5\%$.

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 0.95 for all runs.

Bias error example

Table 2, using two sets of data from a highway in Australia in 2006 collected approximately one month apart, illustrates the calculation of bias error. As the calculated bias error is less than 5%, the test data represents a pass.

It should be noted that these guidelines require 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 surface texture repeatability checks

Chainage (km)	Run 1 (MPD)	Run 2 (MPD)	Run 3 (MPD)	Run 4 (MPD)	Run 5 (MPD)	Mean (MPD)	Standard deviation	Coefficient of variation (%)	Repeatability Requirement 1
100	1.0	1.0	1.0	1.0	1.0	1.00	0.00	0.0	✓
200	1.4	1.5	1.5	1.4	1.5	1.46	0.05	3.8	✓
300	1.4	1.5	1.4	1.4	1.5	1.44	0.05	3.8	✓
400	1.2	1.3	1.2	1.2	1.2	1.22	0.04	3.7	✓
500	1.3	1.3	1.3	1.2	1.3	1.28	0.04	3.5	✓
600	0.9	1	1	1	0.9	0.96	0.05	5.7	✓
700	1.2	1.2	1.2	1.2	1.2	1.20	0.00	0.0	✓
800	1.5	1.5	1.5	1.5	1.5	1.50	0.00	0.0	✓
900	1.5	1.5	1.5	1.5	1.5	1.50	0.00	0.0	✓
1000	1.5	1.5	1.4	1.5	1.5	1.48	0.04	3.0	✓
1100	1.5	1.4	1.5	1.4	1.5	1.46	0.05	3.8	✓
1200	1.8	1.7	1.8	1.7	1.7	1.74	0.05	3.1	✓
1300	1.3	1.3	1.2	1.3	1.2	1.26	0.05	4.3	✓
1400	1.6	1.5	1.5	1.6	1.5	1.54	0.05	3.6	✓
1500	1.7	1.7	1.7	1.6	1.6	1.66	0.05	3.3	✓
1600	1.9	1.8	1.9	1.8	1.8	1.84	0.05	3.0	✓
1700	1.7	1.6	1.6	1.6	1.6	1.62	0.04	2.8	✓
1800	1.7	1.6	1.5	1.6	1.5	1.58	0.08	5.3	✓
1900	1.2	1.2	1.2	1.2	1.2	1.20	0.00	0.0	✓
2000	0.7	0.7	0.8	0.8	0.8	0.76	0.05	7.2	✓
2100	0.8	0.8	0.8	0.8	0.8	0.80	0.00	0.0	✓
2200	1.1	1	1	1	1	1.02	0.04	4.4	✓
2300	0.8	0.8	0.8	0.8	0.8	0.80	0.00	0.0	✓
2400	0.8	0.8	0.8	0.8	1	0.84	0.09	10.6	✗
2500	1	1	1	1	1	1.00	0.00	0.0	✓
2600	0.8	0.8	0.8	0.8	0.8	0.80	0.00	0.0	✓
2700	1.1	1.1	1.1	1.1	1	1.08	0.04	4.1	✓
2800	0.9	0.9	0.9	0.9	0.9	0.90	0.00	0.0	✓
2900	1.1	1.1	1	1.1	1.1	1.08	0.04	4.1	✓
3000	1.3	1.3	1.2	1.3	1.2	1.26	0.05	4.3	✓
3100	0.9	0.9	0.9	0.9	0.9	0.90	0.00	0.0	✓
3200	1.2	1.1	1.1	1.2	1.1	1.14	0.05	4.8	✓

Mean	1.24	1.23	1.22	1.23	1.22	1.23	0.04	2.88	✓
r	0.994	0.994	0.992	0.994	0.989	Repeatability Requirement 3			
r ²	✓ 0.988	✓ 0.988	✓ 0.984	✓ 0.987	✓ 0.977				
Slope	1.069	1.003	1.009	0.964	0.955				
Intercept	-0.069	-0.002	-0.018	0.040	0.048				
								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 surface texture bias error check

Data point (Chainage)	Reference (MPD)	Comparison (MPD)	Calculations	
	\bar{X}_{Ri}	\bar{X}_{Ci}	$\bar{X}_{Ri} - \bar{X}_{Ci}$	$\frac{\bar{X}_{Ri} - \bar{X}_{Ci}}{\bar{X}_{Ri}}$
100	1.00	1.00	0.00	0.00
200	1.46	1.44	0.02	0.01
300	1.44	1.38	0.06	0.04
400	1.22	1.30	-0.08	-0.07
500	1.28	1.30	-0.02	-0.02
600	0.96	1.00	-0.04	-0.04
700	1.20	1.22	-0.02	-0.02
800	1.50	1.56	-0.06	-0.04
900	1.50	1.52	-0.02	-0.01
1000	1.48	1.48	0.00	0.00
1100	1.46	1.50	-0.04	-0.03
1200	1.74	1.68	0.06	0.03
1300	1.26	1.34	-0.08	-0.06
1400	1.54	1.60	-0.06	-0.04
1500	1.66	1.70	-0.04	-0.02
1600	1.84	1.88	-0.04	-0.02
1700	1.62	1.60	0.02	0.01
1800	1.58	1.58	0.00	0.00
1900	1.20	1.26	-0.06	-0.05
2000	0.76	0.82	-0.06	-0.08
2100	0.80	0.80	0.00	0.00
2200	1.02	1.00	0.02	0.02
2300	0.80	0.80	0.00	0.00
2400	0.84	0.92	-0.08	-0.10
2500	1.00	1.08	-0.08	-0.08
2600	0.80	0.84	-0.04	-0.05
2700	1.08	1.10	-0.02	-0.02
2800	0.90	0.94	-0.04	-0.04
2900	1.08	1.12	-0.04	-0.04
3000	1.26	1.36	-0.10	-0.08
3100	0.90	0.98	-0.08	-0.09
3200	1.14	1.14	0.00	0.00

$$\sum_{i=1}^{32} \left(\frac{\bar{X}_{Ri} - \bar{X}_{Ci}}{\bar{X}_{Ri}} \right) = -0.869$$

$$\text{Bias Error} = \left| \frac{100}{32} \cdot \sum_{i=1}^{32} \left(\frac{\bar{X}_{Ri} - \bar{X}_{Ci}}{\bar{X}_{Ri}} \right) \right| = 2.72\% \checkmark$$

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, bias error checks should be conducted over a length of 10 km.

AMENDMENT RECORD

Amendment No.	Sections amended	Action ¹	Date
1 (Initial release)	All (Richard Wix & 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			