AUSTROADS TEST METHOD AG:AM/T012

PAVEMENT RUTTING REPEATABILITY AND BIAS CHECKS FOR A MULTI-LASER PROFILOMETER

1 SCOPE

This test method defines the procedure for conducting repeatability and bias of measurement checks for a vehicle-mounted, laser based rut measurement 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

Austroads Test Method AG:AM/T009. Pavement rutting measurement with a multi-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 multi-laser profilometer as detailed in Austroads Test Method AG:AM/T009.

5 PROCEDURE

5.1 Repeatability checks

(a) Select a clearly defined section of a lane of 10 km total length exhibiting a significant range of rutting at the 100 m segment level.

(b) Following Test Method AG:AM/T009, use the multi-laser profilometer to measure the rut depth in both the left and right wheelpaths. Combine this data into a single dataset containing rut depths from both wheelpaths.

(c) Repeat (b) until five sets of rut depth measurements have been taken.

5.2 Bias error check

(a) Select a clearly defined section of a lane of 10 km total length exhibiting a range of rutting at the 100 m segment level.

(b) Following Test Method AG:AM/T009, use the multi-laser profilometer to measure the maximum rut depth across the lane or in both the left and right wheelpaths. Combine this data into a single dataset containing rut depths from both 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), $S_{nw}\%$, in each wheelpath for each 100 m segment for each series of repeat measurements as follows:

$$S_{nw}\% = 100 \cdot \frac{S_{nw}}{\overline{X}_{nw}}$$

where

$$S_{nw} = \sqrt{\frac{\sum_{i=1}^{N}\left(X_{nwi} - \overline{X}_{nw}\right)^2}{N-1}}$$

$$\overline{X}_{nw} = \frac{\sum_{i=1}^{N} \overline{X}_{nwi}}{N}$$

$w =$ wheelpath

$n =$ segment number

$N =$ total number of measurements in wheelpath w on segment n

$X_{nwi} =$ rutting of wheelpath w, 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, $\overline{S}\%$, as follows:

$$\overline{S}\% = \frac{\sum_{n=1}^{n_s} S_{wn}\%}{N}$$

where

N = twice the total number of segments

6.1.3 Repeatability Requirement 3

Using least squares regression, determine the coefficient of determination, r^2, when the individual rutting values for each wheelpath and segment (dependent variable, *y*) are regressed against the mean values for that wheelpath and 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:

$$BE = \left| \frac{100}{n} \cdot \sum_{w=1}^{2} \left[\sum_{i=1}^{n} \left(\frac{\overline{X}_{Ri} - \overline{X}_{Ci}}{\overline{X}_{Ri}} \right) \right] \right|$$

where

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

$\overline{X}_{Rwi}$ = reference data mean rut depth of wheelpth *w*, segment *i*

$\overline{X}_{Cwi}$ = comparison data mean rut depth of wheelpath *w*, segment *i*

n = twice the 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 rut depth for each 100 m section for each of the five repeat runs

(b) the standard deviation, S_{nw}, for each wheelpath and 100 m segment, for each series of repeat measurements as determined in 6.1.1 (report to the nearest 0.1 mm)

(c) the average of the segment standard deviations, $\overline{S}$, as determined in 6.1.2 (report to the nearest 0.1 mm)

(d) the coefficient of variation for each wheelpath and 100 m segment for each series of repeat measurements, S_{nw}%, as determined in 6.1.1 (report to the nearest 0.1%)

(e) the average of the segment coefficients of variation, $\overline{S}$%, as determined in 6.1.2 (report to the nearest 1%).

(f) the coefficient of determination when the individual rut depth 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 – pass is achieved when 90% of all values are either less than or equal to 1 mm as reported in (b) or less than or equal to 10% as reported in (d)

(h) a statement as to whether Repeatability Requirement 2 has been passed – a pass is achieved when either the value reported in (c) is less than or equal to 1 mm or the value reported in (e) is less than or equal to 7%

(i) a statement as to whether Repeatability Requirement 3 has been passed – pass is achieved when all values reported in (f) are equal to or greater than 0.90.

7.3 Bias error check

Report the following:

(a) the reference data set rut depth for each wheelpath and 100 m section

(b) the comparison data set rut depth for each wheelpath and 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 ≤ 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.

AUSTROADS TEST METHOD AG:AM/T012

PAVEMENT RUTTING REPEATABILITY AND BIAS ERROR CHECKS FOR A MULTI-LASER PROFILOMETER

ANNEX 1 – EXAMPLE OF REPEATABILITY AND BIAS CHECKS

Repeatability example

Table 1, using data from an Australian highway 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 data shown in Table 1 represents a total length of only 3.2 km, and only includes data from a single wheelpath (The truncated data is used here only to ensure that 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 maximum rut depth of each 100 m segment. If data was collected in each wheelpath the checks must be applied for each wheelpath.

It can be seen from the Table that Repeatability Requirement 1 has been passed, as more than 90% of the coefficients of variation between the individual survey runs and the mean of the runs (the far right column in the Table) are ≤ 10% or the standard deviation is ≤ 1 mm.

Repeatability Requirement 2 has been successfully met, with the average of all segments coefficient of variation being ≤ 7% and the average standard deviation is ≤ 1 mm.

Finally, Repeatability Requirement 3 has also been passed, with the r^2 value for the regression relationship between the segment rutting values for each run versus the means of all runs being at least 0.90 for all runs.

Bias error example

Table 2, using data from a highway in Australia in 2006, 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 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 rutting repeatability checks

Chainage (km)	Mean maximum rut depth in each 100 m section (mm)					Average (mm)	Repeatability Requirement 1		
	Run 1	Run 2	Run 3	Run 4	Run 5		St Dev (mm)	COV (%)	Pass
100	5.8	5.4	6.1	5.6	5.4	5.7	0.3	5.2	✓
200	5.8	6.2	5.9	6.2	5.9	6.0	0.2	3.1	✓
300	4.4	4.4	4.3	4.3	4.4	4.4	0.1	1.3	✓
400	5.7	5.4	5.2	5.7	5.2	5.4	0.3	4.6	✓
500	6.7	6.7	5.8	6.7	6.6	6.5	0.4	6.1	✓
600	6	6.1	5.8	6.2	6	6.0	0.2	2.5	✓
700	9.3	9.3	9.4	9.5	9.4	9.4	0.1	0.9	✓
800	12.2	13	12.9	12.2	10.8	12.2	0.9	7.2	✓
900	3.8	3.8	3.8	4	3.9	3.9	0.1	2.3	✓
1000	4.5	4.4	4.4	4.4	4.4	4.4	0.0	1	✓
1100	4.7	4.2	4.4	4.7	4.8	4.6	0.3	5.5	✓
1200	7.1	7.4	7	7.2	7	7.1	0.2	2.3	✓
1300	6.3	6.2	5.3	6.3	6.3	6.1	0.4	7.2	✓
1400	5.1	5.2	4.7	4.8	5.2	5.0	0.2	4.7	✓
1500	6.2	6.1	5.7	5.1	5.9	5.8	0.4	7.5	✓
1600	6.9	6.9	6.7	6.9	7	6.9	0.1	1.6	✓
1700	6.9	6.9	7	6.5	6.7	6.8	0.2	2.9	✓
1800	5.4	5.4	5.9	6.3	6	5.8	0.4	6.8	✓
1900	6.1	5.1	5.5	5.4	6	5.6	0.4	7.5	✓
2000	5.8	5.9	6.6	5.9	5.9	6.0	0.3	5.4	✓
2100	5.4	5.4	5.4	5.3	5.5	5.4	0.1	1.3	✓
2200	4.1	4.2	4.5	3.9	4	4.1	0.2	5.6	✓
2300	3.8	3.5	4	3.7	3.7	3.7	0.2	4.9	✓
2400	6.7	6.2	6.6	5.9	6.2	6.3	0.3	5.2	✓
2500	1.8	1.4	2.5	2	1.6	1.9	0.4	22.7	✓
2600	2	2.2	2.1	2.2	1.6	2.0	0.3	12.3	✓
2700	2.5	2.7	2.5	2.6	2.4	2.5	0.1	4.5	✓
2800	3.6	3	3.6	3.7	3.3	3.4	0.3	8.4	✓
2900	3.7	4	3.9	3.3	3.3	3.6	0.3	9	✓
3000	3.3	2.9	3.2	3.5	3.4	3.3	0.2	7.1	✓
3100	3.6	4	3.6	3.7	3.5	3.7	0.2	5.2	✓
3200	4	3.7	3.7	4.1	3.9	3.9	0.2	4.6	✓
Mean	5.3	5.2	5.3	5.2	5.2	5.2	0.3	5.5%	✓
r	0.996	0.993	0.988	0.993	0.989		Repeatability Requirement 2		
r^2	0.993	0.986	0.976	0.986	0.979				
Slope	1.001	1.057	1.005	0.987	0.950				
Intercept	0.048	-0.309	-0.010	0.080	0.192				
Pass	✓	✓	✓	✓	✓	Repeatability Requirement 3			

Note: Data and analysis are shown here for a single wheelpath and 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 both wheelpaths and a length of 10 km.

Table 2: Example of rutting bias error check

Data point (Chainage)	Reference (Rut Depth) (mm)	Comparison (Rut Depth) (mm)	Calculations	
	$\overline{X}_{Ri}$	$\overline{X}_{Ci}$	$\overline{X}_{Ri} - \overline{X}_{Ci}$	$\frac{\overline{X}_{Ri} - \overline{X}_{Ci}}{\overline{X}_{Ri}}$
100	2.28	2.64	-0.36	-0.158
200	8.08	8.16	-0.08	-0.010
300	7.66	8.08	-0.42	-0.055
400	2.48	2.36	0.12	0.048
500	3.18	3.1	0.08	0.025
600	4.94	4.9	0.04	0.008
700	3.34	3.26	0.08	0.024
800	1.22	1.28	-0.06	-0.049
900	1.12	1.18	-0.06	-0.054
1000	1.46	1.52	-0.06	-0.041
1100	2.48	2.76	-0.28	-0.113
1200	2.5	2.78	-0.28	-0.112
1300	2.68	2.7	-0.02	-0.007
1400	2.22	2.4	-0.18	-0.081
1500	2.08	2.22	-0.14	-0.067
1600	1.9	1.96	-0.06	-0.032
1700	2.62	2.56	0.06	0.023
1800	2.7	2.88	-0.18	-0.067
1900	2.14	2.16	-0.02	-0.009
2000	4.16	4.14	0.02	0.005
2100	3.78	3.88	-0.10	-0.026
2200	3.64	3.88	-0.24	-0.066
2300	9.06	8.84	0.22	0.024
2400	7.34	7.5	-0.16	-0.022
2500	8.36	8.14	0.22	0.026
2600	11.32	10.7	0.62	0.055
2700	7.96	8.54	-0.58	-0.073
2800	12.54	12.92	-0.38	-0.030
2900	10.96	12.16	-1.20	-0.109
3000	4.44	4.28	0.16	0.036
3100	4.26	4.5	-0.24	-0.056
3200	11.42	10.64	0.78	0.068

$$\sum_{i=1}^{32}\left(\frac{\overline{X}_{Ri} - \overline{X}_{Ci}}{\overline{X}_{Ri}}\right) = \quad -0.895$$

$$\text{Bias error} = \left|\frac{100}{32} \cdot \sum_{i=1}^{32}\left(\frac{\overline{X}_{Ri} - \overline{X}_{Ci}}{\overline{X}_{Ri}}\right)\right| = \quad -2.8\% \checkmark$$

Note: Data and analysis are shown here for a single wheelpath and a length of only 3.2 km comprising 32 segments each 100 m long. This is to fit the Table on one page.
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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

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COMMENTARY

1 SCOPE

Additional guidance and background information can be found in the *Austroads Guide to Asset Management – Part 5C: Rutting* (Austroads 2006).

2 REFERENCED DOCUMENTS

No comment.

3 DEFINITIONS

No comment.

4 EQUIPMENT

No comment.

5 PROCEDURE

It is important that the test section contain a range of rutting at the 100 m segment level.

5.1 Repeatability checks

No comment.

5.2 Bias error check

No comment.

6 CALCULATIONS

6.1 Repeatability checks

No comment.

6.2 Bias error checks

No comment.

7 REPORTING

7.1 General details

No comment.

7.2 Repeatability checks

No comment.

7.3 Bias error checks

No comment.

8 FAILED REPEATABILITY AND/OR BIAS ERROR CHECKS

No comment.

ANNEX 1 – EXAMPLE OF REPEATABILITY AND BIAS CHECKS

No comment.

REFERENCES

Austroads 2006, *Guide to asset management – Part 5C: rutting*. AGAM05C/06, Austroads, Sydney.

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This commentary is relevant to the 26 March 2007 release of Austroads Test Method AG:AM/T012.