AUSTROADS TEST METHOD AG:AM/T002

VALIDATION OF AN INERTIAL LASER PROFILOMETER FOR MEASURING PAVEMENT ROUGHNESS (REFERENCE DEVICE METHOD)

1 SCOPE

This test method defines the procedure for performing validation checks of the measurements of pavement roughness determined using a vehicle-mounted inertial laser-based non-contact device (i.e. a laser profilometer), compared to the measurements from a static or manual reference device.

This test method is one of two alternative validation methods required by Austroads Test Method AG:AM/T001 – *Pavement roughness measurement with an inertial laser profilometer*. The other validation method is Austroads Test Method AG:AM/T003.

An example of the calculations and reporting requirements of this Test Method is included as an Annex.

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

ASTM E1364-95 (2000). Standard test method for measuring road roughness by static level method. ASTM International.

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

Austroads Test Method AG:AM/T003. Validation of an inertial laser profilometer for measuring pavement roughness (loop method). March 2007.

Austroads Test Method AG:AM/T004. Pavement roughness repeatability and bias checks for an inertial laser profilometer. March 2007.

Austroads Test Method AG:AM/T005. Distance measurement validation of road condition monitoring vehicles. March 2007.

Austroads Test Method AG:PT/T450. Determination of the International Roughness Index (IRI) using ARRB Walking Profiler. (Previously know as Austroads Test Method PAT01:2001).

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

3 DEFINITIONS

(a) 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) a calibrated inertial laser profilometer as detailed in Austroads Test Method AG:AM/T001

(b) an ARRB Walking Profiler or a surveyor's staff and level.

5 PROCEDURE

5.1 Validation of distance measurement

Test Method AG:AM/T005 must be followed, and its check limits passed, in order to validate the distance measuring equipment used in the profilometer.

5.2 Validation of roughness measurement

(a) Select five test sections of road pavement, each 500 m long, with the following characteristics:

- At least one 500 m test section must have an average IRI roughness of between 0.9 and 1.6 m/km (based on roughness reported at 100 m), i.e. the average of the five 100 m segments must fall within these limits.
- Similarly, at least one section must have an average roughness of between 1.9 and 3.1 m/km
- Similarly, at least one section must have an average roughness of 3.4 m/km or greater.
- The remaining two sections must have average roughness values greater than 1 m/km and less than 7 m/km.
- At least two of the total 25 individual 100 m segments must have a roughness of 4.5 m/km or greater.
- Sections shall be selected so as to ensure that their surface characteristics (materials, texture, etc.) are representative of the road network(s) to be surveyed.
- Sections should be selected with sufficient lead-in to bring the inertial profilometer vehicle up to the highest test speed (nominally 100 km/h) at approach and sufficient length beyond the test site for safe operations.

(b) Measure the single track IRI in both the left and right wheelpaths using either a static level (refer ASTM E1364-95 (2000)) or an ARRB Walking Profiler (refer Test Method AG:PT/T450). When using an ARRB Walking Profiler, this step should be repeated to obtain two sets of readings in each wheelpath, and the average determined IRI of each wheelpath.

(c) Following Test Method AG:AM/T001, use the inertial profilometer to measure the single track IRI in both the left and right wheelpaths of each sections at a test speed near the bottom of the profilometer's specified operating range. Repeat at a test speed near the mid-range of the profilometer's operating range. Repeat again at a test speed near the top of the operating range.

(d) Repeat (c) four times to obtain a total of five sets of readings for each of the three test speeds.

(e) Additionally, Test Method AG:AM/T004 must be followed, and its check limits passed, in order to validate the repeatability and bias error of test measurements for the equipment, operator, and driver.

6 CALCULATIONS

(a) Determine the Lane IRI for each 100 m segment of each test section for all of the test runs from both the inertial profilometer and the reference measurements (ARRB Walking Profiler or staff and level readings). The Lane IRI is determined using the following equation:

$$Lane\ IRI_{qc} = \frac{IRI_{qcL} + IRI_{qcR}}{2}$$

where

$Lane\ IRI_{qc}$ = lane roughness (IRI m/km)

IRI_{qcL} = roughness of left wheel path profile (IRI m/km)

IRI_{qcR} = roughness of right wheel path profile (IRI m/km)

(b) For each of the three speeds, group the IRI data measured by the inertial profilometer into a single set of data, totalling 125 records (one speed x five sections x five chainages per section x five repeat survey runs per sections). Using least squares regression, a line of best fit between the two sets of results should be identified for each speed in the form:

$$IRI_{\text{Base}} = A \cdot IRI_{\text{Profilometer}} + B$$

where

IRI_{Base} = Lane IRI calculated from the base reference measurements (i.e. either ARRB Walking Profiler, or staff and level)

$IRI_{\text{Profilometer}}$ = Lane IRI calculated from the operational laser profilometer

A = regression equation slope

B = regression equation intercept

The coefficient of determination, r^2, for each regression must also be determined.

(c) Group all of the IRI data measured by the inertial profilometer into a single set of data, totalling 375 records (three speeds x five sections x five chainages per section x five repeat survey runs per section). Using least squares regression, a line of best fit between the two sets of results should be identified in the form:

$$IRI_{Base} = A \cdot IRI_{Profilometer} + B$$

where

IRI_{Base} = Lane IRI calculated from the base reference measurements (i.e. either ARRB Walking Profiler, or staff and level)

$IRI_{Profilometer}$ = Lane IRI calculated from the operational laser profilometer

A = regression equation slope

B = regression equation intercept

The coefficient of determination, r^2, for the regression must also be determined.

7 REPORTING

7.1 Validation of distance measurement

Report the items required by Test Method AG:AM/T005.

7.2 Validation of roughness measurement

Report the following:

(a) the location of each section tested

(b) date and time of validation checks

(c) identification of laser profilometer and base instruments used

(d) for each section and survey speed, the calculated IRI values for each wheelpath and the lane using both the laser profilometer and the reference method

(e) for each of the three test speeds, the slope A, intercept B, and coefficient of determination, r^2, calculated in 6(b)

(f) for all of the results combined, the slope A, intercept B, and coefficient of determination, r^2, calculated in 6(c)

(g) a statement as to whether the profilometer passes or fails validation of profile measurement – the profilometer is considered to have passed the profile measurement validation if all the values reported in 6(b) and 6(c) fall within the following ranges:

individual speeds (6(b)):	$0.95 \le A \le 1.05$	$-0.25 \le B \le 0.25$ m/km	$r^2 \ge 0.950$
combined results (6(c)):	$0.97 \le A \le 1.03$	$-0.25 \le B \le 0.25$ m/km	$r^2 \ge 0.975$

8 FAILED VALIDATION

In the event that the profilometer fails the validation process, causes for the failure must be investigated, defects rectified and this test method repeated.

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ANNEX 1 – EXAMPLE OF VALIDATION CHECKS

Roughness validation example

Reference data (eg. average Walking Profiler)

Chainage (m)	Lane IRI_{qc} (m/km)	Chainage (m)	Lane IRI_{qc} (m/km)	Chainage (m)	Lane IRI_{qc} (m/km)	Chainage (m)	Lane IRI_{qc} (m/km)	Chainage (m)	Lane IRI_{qc} (m/km)
SECTION A		SECTION B		SECTION C		SECTION D		SECTION E	
100	1.94	100	3.42	100	1.75	100	2.48	100	1.12
200	2.01	200	5.72	200	1.53	200	2.12	200	1.30
300	2.92	300	4.68	300	1.97	300	1.01	300	1.78
400	5.08	400	2.86	400	1.64	400	1.61	400	1.40
500	5.00	500	3.72	500	1.06	500	2.11	500	1.86

Average section characteristics

Section	IRI_{qc} m/km		
	Min	Max	Average
A	1.94	5.08	3.4
B	2.86	5.72	4.1
C	1.06	1.97	1.6
D	1.01	2.48	1.9
E	1.12	1.86	1.5
All	1.01	5.72	2.5

Are the validation site requirements met?

One section 0.9 <= Roughness <= 1.6 m/km	**passed**
One section 1.9 <= Roughness <= 3.1 m/km	**passed**
One section Roughness >= 3.4 m/km	**passed**
Two segments Roughness >= 4.5 m/km	**passed**

Section	Chainage	Reference (IRI m/km) (base)	Speed	Lane IRI_{qc} (m/km) (profilometer) Run 1	Run 2	Run 3	Run 4	Run 5
A	100	1.94	25	1.80	1.84	1.77	1.83	1.80
A	200	2.01	25	1.89	1.88	1.87	1.85	1.83
A	300	2.92	25	2.53	2.55	2.52	2.52	2.50
A	400	5.08	25	4.94	4.97	4.85	4.84	4.89
A	500	5.00	25	4.64	4.59	4.61	4.60	4.60
B	100	3.42	25	3.57	3.52	3.48	3.51	3.55
B	200	5.72	25	5.71	5.74	5.73	5.73	5.74
B	300	4.68	25	4.58	4.59	4.64	4.58	4.60
B	400	2.86	25	2.85	2.87	2.87	2.87	2.83
B	500	3.72	25	3.44	3.45	3.46	3.45	3.44
C	100	1.75	25	1.80	1.82	1.81	1.81	1.82
C	200	1.53	25	1.51	1.54	1.55	1.55	1.55
C	300	1.97	25	1.94	2.02	2.01	1.98	2.01
C	400	1.64	25	1.57	1.65	1.65	1.67	1.64
C	500	1.06	25	1.07	1.10	1.09	1.09	1.10
D	100	2.48	25	2.50	2.51	2.51	2.43	2.45
D	200	2.12	25	2.06	2.04	2.05	2.04	2.03
D	300	1.01	25	0.93	0.93	0.93	0.91	0.91
D	400	1.61	25	1.58	1.54	1.53	1.54	1.58
D	500	2.11	25	2.10	2.07	2.11	2.08	2.08
E	100	1.12	25	1.10	1.09	1.09	1.09	1.09
E	200	1.30	25	1.24	1.26	1.26	1.24	1.24
E	300	1.78	25	1.76	1.77	1.77	1.81	1.75
E	400	1.40	25	1.34	1.33	1.37	1.35	1.34
E	500	1.86	25	1.85	1.85	1.90	1.86	1.89
A	100	1.94	50	1.79	1.83	1.75	1.73	1.80
A	200	2.01	50	1.94	1.94	1.94	1.89	1.89
A	300	2.92	50	2.53	2.56	2.59	2.53	2.48
A	400	5.08	50	5.00	5.02	5.02	5.10	4.92
A	500	5.00	50	4.74	4.74	4.66	4.73	4.69
B	100	3.42	50	3.63	3.64	3.59	3.60	3.59
B	200	5.72	50	5.76	5.79	5.81	5.82	5.81
B	300	4.68	50	4.73	4.64	4.72	4.71	4.70
B	400	2.86	50	2.89	2.97	2.93	2.97	2.96
B	500	3.72	50	3.55	3.52	3.57	3.52	3.56
C	100	1.75	50	1.81	1.82	1.81	1.81	1.82
C	200	1.53	50	1.52	1.53	1.52	1.51	1.53
C	300	1.97	50	2.01	1.99	2.00	2.00	2.01
C	400	1.64	50	1.68	1.67	1.69	1.71	1.70
C	500	1.06	50	1.08	1.08	1.10	1.11	1.09
D	100	2.48	50	2.55	2.51	2.49	2.52	2.50
D	200	2.12	50	2.09	2.07	2.05	2.08	2.08
D	300	1.01	50	0.97	0.96	0.96	0.97	0.95
D	400	1.61	50	1.53	1.54	1.56	1.56	1.54
D	500	2.11	50	2.13	2.08	2.09	2.15	2.13
E	100	1.12	50	1.09	1.09	1.09	1.09	1.10
E	200	1.30	50	1.29	1.26	1.26	1.24	1.29
E	300	1.78	50	1.76	1.77	1.77	1.81	1.77
E	400	1.40	50	1.35	1.33	1.37	1.35	1.35
E	500	1.86	50	1.82	1.85	1.90	1.86	1.88
A	100	1.94	95	1.75	1.69	1.74	1.71	1.70
A	200	2.01	95	1.83	1.86	1.89	1.85	1.74
A	300	2.92	95	2.57	2.56	2.58	2.52	2.65
A	400	5.08	95	5.01	4.91	5.01	5.01	5.01
A	500	5.00	95	4.84	4.78	4.79	4.75	4.79
B	100	3.42	95	3.49	3.50	3.50	3.57	3.51
B	200	5.72	95	5.88	5.91	5.98	5.92	5.94
B	300	4.68	95	4.84	4.81	4.85	4.76	4.85
B	400	2.86	95	2.78	2.90	2.79	2.83	2.80
B	500	3.72	95	3.54	3.62	3.61	3.60	3.63
C	100	1.75	95	1.84	1.87	1.83	1.84	1.87
C	200	1.53	95	1.50	1.50	1.50	1.50	1.50
C	300	1.97	95	2.00	2.02	2.00	2.00	1.98
C	400	1.64	95	1.70	1.71	1.72	1.70	1.69
C	500	1.06	95	1.12	1.15	1.12	1.13	1.11
D	100	2.48	95	2.49	2.51	2.56	2.52	2.48
D	200	2.12	95	2.09	2.12	2.12	2.09	2.12
D	300	1.01	95	0.98	0.94	0.99	0.96	1.00
D	400	1.61	95	1.60	1.62	1.61	1.56	1.59
D	500	2.11	95	2.11	2.09	2.12	2.14	2.14
E	100	1.12	95	1.11	1.11	1.11	1.11	1.11
E	200	1.30	95	1.34	1.34	1.34	1.32	1.32
E	300	1.78	95	1.76	1.78	1.78	1.73	1.77
E	400	1.40	95	1.39	1.38	1.38	1.38	1.38
E	500	1.86	95	1.91	1.92	1.92	1.93	1.92

Low speed

$IRI_{base} = A \times IRI_{profilometer} + B$

A	1.03
B	0.00
r^2	0.992

Are the validation requirements met?

0.95 <= A <= 1.05	**passed**
-0.25 <= B <= 0.25	**passed**
r^2 >= 0.95	**passed**

Medium speed

$IRI_{base} = A \times IRI_{profilometer} + B$

A	1.00
B	0.02
r^2	0.992

Are the validation requirements met?

0.95 <= A <= 1.05	**passed**
-0.25 <= B <= 0.25	**passed**
r^2 >= 0.95	**passed**

High speed

$IRI_{base} = A \times IRI_{profilometer} + B$

A	0.99
B	0.04
r^2	0.992

Are the validation requirements met?

0.95 <= A <= 1.05	**passed**
-0.25 <= B <= 0.25	**passed**
r^2 >= 0.95	**passed**

All combined

$IRI_{base} = A \times IRI_{profilometer} + B$

A	1.02
B	0.01
r^2	0.992

Are the validation requirements met?

0.97 <= A <= 1.03	**passed**
-0.25 <= B <= 0.25	**passed**
r^2 >= 0.975	**passed**

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