

# APPENDIX E

## MEASURING PAVEMENT ROUGHNESS

### INTRODUCTION

In order to provide a measure of pavement surface condition that has nationwide consistency and comparability and is as realistic and practical as possible, a uniform, calibrated roughness measurement for paved roadways is required by the HPMS.

Roughness is defined in accordance with ASTM E867 as “The deviation of a surface from a true planar surface with characteristic dimensions that affect vehicle dynamics and ride quality.” After a detailed study of various methodologies and road profiling statistics, the International Roughness Index (IRI) was chosen as the HPMS standard reference roughness index. The summary numeric (HPMS data reporting unit) is the IRI in meters/kilometer (inches/mile). The primary advantages of the IRI are:

1. It is a time-stable, reproducible mathematical processing of the known profile.
2. It is broadly representative of the effects of roughness on vehicle response and user’s perception over the range of wavelengths of interest, and is thus relevant to the definition of roughness.
3. It is a zero-origin scale consistent with the roughness definition.
4. It is compatible with profile measuring equipment available in the U.S. market.
5. It is independent of section length and amenable to simple averaging.
6. It is consistent with established international standards and able to be related to other roughness measures.

### HPMS ROUGHNESS MEASUREMENT PROCEDURE

The reference method for obtaining IRI data for the HPMS can be found in the AASHTO Standard Practice for Determination of International Roughness Index for Quantifying Roughness of Pavements, AASHTO PP 37-04. This Standard Practice calls for the use of a longitudinal profile measured in accordance with ASTM E-950 as a basis for estimating IRI. AASHTO PP 37-04 is reproduced in this appendix with the written consent of AASHTO. Roughness is reported for HPMS in IRI units of either m/km or in/mi (1 m/km = 63.36 in/mi).

Roughness data should be reported in IRI units for all sections in accordance with Table IV-1 in Chapter IV. The lower functional systems (rural and urban collector and urban minor arterial) have been placed in the “recommended” category since there are situations where it may not be possible to obtain meaningful roughness measurements with profiling equipment. Major obstacles include:

Speed restrictions	Traffic congestion
Short section lengths	Pavement treatments
Numerous traffic signals	Intersection treatments

However, some of these obstacles can be overcome by collecting roughness data during non-peak hours or at night, where speed, traffic, and safety are less of a problem. There are situations where it also may

not be possible to obtain meaningful roughness measurements on some urban other principal arterial sections. In these cases, a value of “0” may be reported.

All equipment must be operated within manufacturer’s specifications; quality assurance guidelines outlined in AASHTO PP 37-04, Section 5, and Appendix B, must be followed. Each State should document and retain records of its quality assurance procedures; FHWA field offices should monitor adherence to these procedures as part of roughness data process reviews.

## **ADDITIONAL RECOMMENDATIONS FOR COLLECTION OF ROUGHNESS DATA**

The following field survey guidelines are recommended for State use in addition to the AASHTO Standard Practice:

- Where roughness data are collected in both directions, the State should use the “inventory direction” selected in accordance with the discussion on page IV-2 of the HPMS Field Manual for reporting IRI data and should use this same direction for all future HPMS reporting.
- For multi-lane facilities, roughness data for the outside (right) lane should be reported. However, if this is not practical, whichever lane is measured should be used for all future HPMS reporting.
- Roughness data collection should be performed when the pavement is in stable condition. Data should not be collected during winter (frost/freeze or freeze/thaw) or wet base conditions. Data collection should be performed during good weather conditions when wind conditions will not affect equipment stability and on dry pavement. All equipment manufacturer’s recommended procedures should be observed.
- Data should only be collected at the speeds that correspond to the manufacturer’s recommended speed range. Constant speeds should be maintained for all measurements within specified ranges.
- Exclude the impacts of bridge approaches and railroad crossings (or other localized discontinuities) from the roughness measurement for the roadway. Bridge decks should not be included; the objective is to obtain a measure of pavement not bridge roughness.
- Roughness measurements should be taken over the entire length of an HPMS roadway section. However, in order to achieve equipment and speed stability, a minimum run-in length, consistent with the manufacturer’s specification, may be required prior to the beginning of the measurement area. If this minimum cannot be met prior to the start of the sample section, a shorter portion of the HPMS section may be measured, but that same portion should always be measured in future roughness data collection activities. Short HPMS sections also may be included in slightly longer roughness test sections for measurement and reporting purposes. However, the same longer sections should always be measured in future data collections.

## **COORDINATION WITH OTHER ACTIVITIES**

One of the goals of HPMS is to avoid duplicate data collection efforts. States are encouraged to coordinate roughness measurement activities, where possible, such that the same equipment, verification sites, and measurements are used for multiple purposes. Therefore, HPMS activities should be coordinated with other State activities such as the Strategic Highway Research Program (SHRP)/Long Term Pavement Performance (LTPP) and the State Pavement Management Systems (PMS).

The LTPP activities monitor pavement performance and use in detail for approximately 1,500 pavement sections nationwide as part of SHRP. The pavement and traffic monitoring data collected on LTPP sections should be used for the HPMS universe or standard sample sections where possible. In addition, ef-

forts should be made to utilize the LTPP established sections/profiles as multiple-use verification sections in each State.

Many State and some local transportation agencies have operational or are developing a PMS to guide program development, improve life-cycle costs, and help select the most effective pavement improvement strategies. The HPMS pavement data reporting should make full use of existing PMS data and collection activities. Data collected by others (cities, counties, MPO's, etc.) should be subjected to the same AASHTO quality assurance guidelines before incorporation into the HPMS.

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**Standard Practice for**

**Determination of International  
Roughness Index (IRI) to Quantify  
Roughness of Pavements**

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AASHTO Designation: PP 37-04



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 Standard Practice for

## Determination of International Roughness Index (IRI) to Quantify Roughness of Pavements

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 1. SCOPE

- 1.1. This practice describes a method for estimating roughness for a pavement section. An International Roughness Index (IRI) statistic is calculated from a single longitudinal profile measured with a road profiler in both the inside and outside wheelpaths of the pavement. The average of these two IRI statistics is reported as the roughness of the pavement section.
- 1.2. The practice recognizes the need for a quality assurance (QA) plan and proposes guidelines for the development of a QA plan.
- 1.3. Measurements of profile are made in accordance with ASTM E 950. If any part of this practice is in conflict with its references made, such as ASTM standards, this practice takes precedence for its purpose.
- 1.4. *This practice does not purport to address all of the safety issues, if any, associated with its use. It is the responsibility of the user of this practice to establish appropriate safety and health practices and determine the applicability of regulatory limitations related to and prior to its use.*

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 2. REFERENCED DOCUMENTS

- 2.1. *ASTM Standards:*
- E 867, Terminology Relating to Vehicle-Pavement Systems
  - E 950, Standard Test Method for Measuring the Longitudinal Profile of Traveled Surfaces with an Accelerometer Established Inertial Profiling Reference
  - E 1166, Guide for Network Level Pavement Management
- 2.2. *Other Documents:*
- Karamihas, S. M., T. D. Gillespie, R. W. Perera, and S. D. Kohn. *NCHRP Report 434: Guidelines for Longitudinal Pavement Profile Measurement*. TRB, National Research Council, Washington, DC, 1999.
  - Sayers, Michael W. On the Calculation of IRI from Longitudinal Road Profile. University of Michigan, Transportation Research Institute, Preprint TRB, 74th Annual Meeting, Washington, DC, January 1995.
  - Sayers, Michael W., T. D. Gillespie, and W. D. O. Paterson. *Guidelines for Conducting and Calibrating Road Roughness Measurements. The World Bank Technical Paper, Number 46*, The World Bank. 1986.

- Sayers, M. W., and S. M. Karamihas. Interpretation of Road Roughness Profile Data. FHWA-RD-96-101. Federal Highway Administration, U.S. Department of Transportation, Washington, DC, 1996.

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### 3. SIGNIFICANCE AND USE

- 3.1. This practice outlines standard procedures for measuring longitudinal profile and calculating the International Roughness Index (IRI) for highway pavement surfaces to help produce consistent estimations of IRI for network-level pavement management.

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### 4. TERMINOLOGY

4.1. *Definitions:*

- 4.1.1. *roughness*—according to ASTM E 867, the deviation of a surface from a true planar surface with characteristic dimensions that affect vehicle dynamics and ride quality. In this practice, the term *roughness* is the average of two IRI statistics calculated from longitudinal profile measurements, one in each pavement wheelpath.
- 4.1.2. *longitudinal profile*—the set of perpendicular deviations of the pavement surface from an established horizontal reference plane taken along a travel lane.
- 4.1.3. *international roughness index (IRI)*—a statistic used to estimate the amount of roughness in a measured longitudinal profile. The IRI is computed from a single longitudinal profile using a quarter-car simulation as described in the report “On the Calculation of IRI from Longitudinal Road Profile” (Sayers 95). Computer programs are referenced in Appendix A of this procedure to calculate the IRI statistic from a longitudinal profile.

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### 5. QUALITY ASSURANCE

- 5.1. Agencies using this practice are required to develop a satisfactory quality assurance (QA) plan. At a minimum, the plan shall include the requirements listed in the following sections.
- 5.1.1. Qualification and training records of individuals conducting the survey;
- 5.1.2. Accuracy and calibration records of equipment used in the survey; and
- 5.1.3. Periodic and ongoing quality control program and the content of the program.
- Note 1**—The estimate of roughness of pavements can be used both at network- and project-level pavement management. Guidelines for network level are included in ASTM E 1166, which can be used as a source for the development of a QA plan.
- Note 2**—The guidelines that can be used for the development of a quality assurance program are given in Appendix B.

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### 6. DATA COLLECTION

- 6.1. Agencies using this practice are expected to designate the lane(s) and direction(s) of travel to be surveyed based on sound engineering principles and management needs within the agency.

- 6.2. Locate (place) the two sensors, separated approximately 58 in. to 71 in. in the wheelpaths. The longitudinal profile points used for calculating the IRI shall have a longitudinal spacing not greater than 6 in. Long wavelength filters are used to remove all wavelengths exceeding 300 ft.

**Note 3**—The use of anti-aliasing filters and averaging to remove small wavelength content from the profile is left to the discretion of the agency and equipment manufacturers.

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## 7. CALCULATIONS

- 7.1. Calculate IRI values for each 0.1 mile for both wheelpaths. Compute an average of the two IRI values to determine roughness.

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## 8. REPORT

- 8.1. Report the roughness calculated in Section 7.1 to the nearest inch per mile. This does not preclude more accurate recording of the IRI.
- 8.2. Use the length of the data summary interval of 0.1 mile.
- 8.3. *The minimum data recorded and stored for each section shall include:*
- 8.3.1. *Section Identification*—List all available information necessary to locate the section using agency's current referencing system;
- 8.3.2. IRI for each of the two wheelpaths (in./mi);
- 8.3.3. Average of both IRIs calculated for the section (in./mi);
- 8.3.4. Date of data collection (month/day/year);
- 8.3.5. Length of section in feet for which the data is collected.
- 8.3.6. Profile sampling interval;
- 8.3.7. Long wavelength filter setting; and
- 8.3.8. *Optional*—Pavement surface temperature.

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## APPENDICES

(Nonmandatory Information)

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### A1. FORTRAN PROGRAM TO CALCULATE IRI FROM PROFILE

**Note 4**—A software program is available from the University of Michigan Transportation Research Institute (UMTRI), named RoadRuf. This Microsoft Windows based software contains procedures for calculating IRI and many other profile analysis capabilities. The software can be

made to comply with the requirements of this protocol. It is public domain and can be downloaded from the World Wide Web at <http://www.umtri.umich.edu>. Setup options are discussed in the accompanying documentation.

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**B1. GUIDELINES—QUALITY ASSURANCE PLAN**

- B1.1. *Quality Assurance (QA) Plan*—Each agency shall develop a quality assurance plan. The plan shall include survey personnel certification training records, accuracy of equipment, daily quality control (QC) procedures, and periodic and on-going QC activities. The following guidelines can be used for developing such a plan.
- B1.2. *Certification and Training*—Agencies are individually responsible for training and/or certifying their data collection personnel and contractors for proficiency in using the profile measuring equipment according to this practice and other applicable agency procedures.
- B1.3. *Equipment Calibration*—Equipment Calibration (accelerometers and non-contact sensors) is done in accordance with specific manufacturer recommendations. The equipment must operate within the manufacturer's specifications. A regular maintenance and testing program is established for the equipment in accordance with the manufacturer's recommendations.
- B1.4. *Verifications Sections*—Verifications sections are selected with previously determined IRI statistics for both wheelpaths. These sections are measured by equipment operators on a regular basis. Evaluations of these measurements can provide information about the accuracy of field measurements and give insight into needed equipment calibration. Verification sections are rotated on a regular basis in order to assure that the operators are not repeating previously known IRI statistics during the verification. An alternate to verification sections is to re-measure and compare up to five percent of the data as a daily or weekly quality check to insure system stability and repeatability.
- B1.5. *Quality Checks*—Additional quality checks can be made by comparing last year's IRI statistics with current measurements. At locations where large changes occur, the pavement manager may require additional checks of the data.



