Recommend Approval:	Rebeccah Smith	6-27-12	Maryland Department of Transportation State Highway Administration Office of Materials Technology MARYLAND STANDARD METHOD OF TESTS	
	Team Leader	Date		
	[signature]	6/27/12		
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Approved:	Tim Smith	07/10/12	OPERATION OF THE INERTIAL PROFILER	MSMT 563
	Director	Date		

SCOPE:

This procedure is used to measure pavement roughness using an inertial profiler with laser height sensors. A vehicle containing the sensors and electronic processing equipment is driven over the pavement to be measured. A computer-generated profile is used to derive the International Roughness Index and to identify defects that exceed a specific threshold.

REFERENCE DOCUMENTS:

ASTM E 950 Standard Test Method for Measuring the Longitudinal Profile of Traveled Surfaces with an Accelerometer Established Inertial Profiling Reference.

Sayers, Michael W., and Karamihas, Steven M. "The Little Book of Profiling", University of Michigan Transportation Institute, Ann Arbor, Michigan, 1998.

National Cooperative Highway Research Program Report 434 "Guidelines for Longitudinal Pavement Profile Measurement" 1999.

TERMINOLOGY:

Accelerometer is a transducer that provides an output proportional to acceleration.

Aliasing is the error which results from sampling a long wavelength signal that is mixed with a short wavelength noise signal.

Anti-Aliasing Filter is a low pass filter. It suppresses short wavelength contamination of longer wavelength measurements to improve the accuracy of the sampling process.

Filtering is a procedure to extract desired information from a signal that also contains unwanted information (commonly called noise). Digital filtering is a calculation procedure that takes one set of numbers and transforms them into another set in which the noise is reduced. Moving averages are one type of such transform or filter.

High-Pass Filtering reduces the effect of long wavelengths that are associated with gradual elevation changes such as hills.

Index is a measure or standard. Within the context of this test method, a suitably chosen index quantifies the ride quality of a pavement.

Inertial Profiler is a vehicle that has to be moving in order to measure and record the elevations profiles of a roadway from which roadway roughness is determined.

Infrared Laser Sensor is a non-contacting transducer that provides an output proportional to the distance from the sensor to a reflecting surface. These sensors are mounted at a nominal height, or standoff, above the roadway surface when the test vehicle is in the static position.

Low-Pass Filter is a smoothing type filter. It reduces the effect of short wavelengths that are associated with rapid elevation changes such as expansion joint ribs.

Measurement Range is the detectable range of heights, measurable by the sensor.

Moving Average is a filtering process whereby each data point is replaced with the average value of several adjacent points or elevations. It is a smoothing process because the changes from one elevation point to the next will not be as significant due to the fact that the difference has been divided by the total number of data points in the averaging scheme. It is a type of "low-pass" filter.

Profile is a two-dimensional slice of the roadway surface, taken along an imaginary line, such as the wheel path, in the longitudinal or travel direction. It represents the perpendicular deviations of the pavement surface from an established reference parallel to the horizontal.

Reference Line is the imaginary line formed by the infrared laser sensor and the accelerometer in a static mode.

Repeatability is consistency in successive measurements of the same quantity over time. It is a quantifier of the variability in measurement error.

Roughness is the deviation of the roadway surface from a true horizontal surface, due to surface finish, aggregate texture, the underlying layers etc. All of the properties that induce vertical motion in traveling vehicles contribute to the roughness (or lack of smoothness) of the traveled surface that is being evaluated.

Sensors are devices that measure quantities. They are responsive to a change in a physical measurement such as distance, temperature, or acceleration.

Sample Interval is the longitudinal distance between data capture points. The data includes height and accelerometer values. This is different from the sampling rate of the sensors, which is typically much faster

Report Interval is the travel distance between the output of an elevation for the creation of a profile or is used for the calculation of derivative indexes.

Standoff Distance is the distance from the light source to a point in the center of the measurement range.

Transducer is a device that converts variables of one type (i.e. distance) into those of another type (i.e. voltage). These conversions must conform to a known transformation (i.e. proportional) to be useful.

SUMMARY OF METHOD:

This test method provides a means for measuring the roughness of existing, new, or rehabilitated pavement surfaces. The resultant International Roughness Index (IRI) will indicate a riding condition of the highway pavement. Low roughness can increase the roadway's durability, improve ride quality, and reduce operating cost for the motorist.

APPARATUS:

1. The Inertial Profiler is a test vehicle conforming to E 950 Class I/II containing the following minimum equipment:

- **(a)** Accelerometers
- **(b)** Infrared Laser Sensors
- **(c)** Distance Measurement Instrument
- **(d)** Data Acquisition System
- **(e)** On Board Computer
- **(f)** On Board Display
- **(g)** External Data Storage Device
- **(h)** Calibration Blocks
- **(i)** Automated start and stop triggering device

2. The On Board Computer in the test vehicle shall be capable of collecting and analyzing data from the sensors. The computer shall generate a simulated profile and calculate IRI and provide data on defects greater than a specified threshold. The computer shall be capable of providing the following information:

(a) Report the appropriate date, time, contract number, route, location, testing directions, lane, and operator data, software versions for data collection and processing, filter settings, and data collection speed.

(b) Record the equipment parameters relating to calibration and settings.

(c) Provide a generated profile, using a scale of 1 in. = 25 ft for horizontal measurements and a 1:1 scale for vertical measurements.

(d) Report the accumulated distance or station number for each 25 ft section in whole numbers. Report the IRI for each wheel path for each section, the average IRI of the two wheel paths for each section, and the average IRI for the entire run. Report sections are 25 ft long and one lane wide. Tested sections shorter than 25 ft due to exempt areas [535.03.02(b)] or the project end will be ignored for purposes of pay adjustment, but still shall be measured and reported.

(e) Note the vertical measurements on exempt areas, along with continuing to accumulate odometer measurements. These readings shall be omitted from the readings used for any pay adjustments.

3. The profiler shall take measurements in both wheel paths simultaneously, with spacing between the wheel paths from 67 to 69 in.

CALIBRATION:

General

Based on the nature of the equipment and the precision level required, it necessitates the establishment of a regular calibration schedule. The manufacturer of this equipment has a recommended schedule that can be used as a guide for a regular schedule. The equipment should be calibrated according to the manufacturer's calibration and on a monthly basis as a minimum.

Transducers and Sensors

Accelerometer. All accelerometers shall be self-calibrating. This calibration feature may be internal or external. After calibration, the accelerometer shall display an alarm when it detects an abnormal value for acceptance or rejection by the operator.

Displacement Transducer. The manufacturer shall provide detailed calibration procedures that are to be followed. This typically involves:

Displacement transducers are calibrated in a static mode with the operator in the test vehicle. The first distance to be checked is the standoff distance. This check is accomplished by having the transducers measure the distance to a calibration bar. The top end of this bar is at the standoff distance. When the sensors are reading the calibration bar correctly, an accurately measured step is placed underneath the transducers. The readings obtained are then compared to those that should be indicated by the sensors, taking into consideration the readings that were obtained at the standoff height and the block thickness. Typical values for the standoff height are 8.0 to 16.0 in. and a block thickness of 2.0 in. To check linearity, a second 4.0 in. block may be used. Once calibrated, an alarm should be triggered if a height beyond a specified range is detected.

Distance Transducer. Distance transducers come with manufacturer recommendations on calibration. This usually involves the following:

A predetermined segment of roadway is first established. This is normally at least 1000 ft in length. The vehicle, with the distance transducer turned on, is driven along this reference segment and a reading of pulses is obtained. Several runs are made of the same segment. Then the average pulse count is computed and entered as the calibration constant. Distance transducers should be checked according to their manufacturers recommended frequency, when vehicle tires are changed, total vehicle weight including operator is changed, or when there is a question about their performance.

The distance-measuring device should generate an alarm if it detects unreliable signals from its transducer.

Annual Approval. All profilers used on Administration projects will be approved annually at a designated state facility. This approval is in addition to the Standardization testing. For approval, the profiler shall be subjected to a series of tests to verify its ability to measure standardized profiles with the required accuracy. All filters and mathematical transforms that are built into the processing system that create the IRI will also be checked.

Standardization. All profilers used on Administration projects shall be standardized on an administration-established, specified test site on a regular basis. Three runs on one of the test sites shall be completed within the previous 60 calendar days before profiling a project. These three runs shall meet the repeatability requirements shown in the Calculations section. The standardization test results will provide a measurement baseline for comparison of quality control and quality assurance test results at the project level. The following test sites, each 0.2 miles in length, are for use as Standardization Test Sites:

1. **Allegany County**: MD 144 (Old National Pike), east of Flintstone Elementary School. Off of I 68 at exit #56 to MD 144 - National Pike : Flintstone. Test site signs are posted in the Eastbound direction.

2. **Talbot County**: MD 662 (Centreville Road), between Airport Road and Forest Street. Located off of US 50 near the Easton Airport. Test site signs are posted in the Northbound direction.

PROJECT TEST SECTION SETUP:

1. When ready to profile a project, begin at the limit of paving.

- **a.** Measure 50 ft in the direction of travel and mark the limit of profiling at the start of the project.

- **b.** From the start of profiling, report IRI in 25 ft sections.

- **c.** Mark the end of profiling at any “Area Not Profiled” [Section 535.03.02] or the limit of profiling at the end of the project (50 ft before the limit of paving).

- **d.** After an “Area Not Profiled”, mark the beginning of a new 25 ft section. Any resulting section less than 25 ft in length shall be ignored for purposes of pay adjustments.

- **e.** Repeat this process for the other direction of travel on the project. Note that the section breaks may be at different locations for each direction of travel.

- **f.** Sections prior to an “Area Not Profiled” or the last section on the project in each direction of travel are the only sections that might be less than 25 ft.

- **g.** For dual lane or wider roadways, mark the limits of profiling and “Area Not Profiled” across all lanes in the same travel direction at the same point. This may result in slightly more than 50 ft being ignored for profiling in some lanes at skewed bridges on multi lane roads.

2. During the paving operation, if the end of a days production does not occur at the limit of work or at an "area not Profiled", then profile the resulting partial section, area less than 25 ft long, and the transverse joint with the next paving days production as a full 25 ft section. The result will be IRI reported for full 25 ft sections with no partial sections due to the end of a paving shift.

TESTING PROCEDURE:

General

System Power. Electronic equipment should be turned on and warmed up before any testing is performed. Refer to the manufacturer's manual for the stabilization period.

System Parameters. Selection of wavelength limits, available indices, etc. must be checked to comply with the following:

1. Long wavelength filter - 300 ft
2. Short wavelength filter - 0.5 ft

Calibration Checks. Perform system calibration checks prior to any testing as outlined in the section above.

Measuring Speed. Driving speed shall be as nearly constant during testing as can be maintained. Often better results are obtained at speeds in the normal driving range. The selected measuring speed shall be within the range that was utilized when the equipment was most recently approved.

Sudden changes in speed should be avoided (i.e. hard braking) while testing. This may give erroneous readings if the light beam falls outside the standoff range, or the sensors are not perfectly vertical.

Test Location. When preparing to run a test on a roadway, it is recommended that the operator become familiar with the project, its limits, and other outstanding features to facilitate safe testing at a constant speed.

Data Acquisition. Enter the information on the operator, project, and equipment parameters. For the test data, collection shall be done in the direction of travel for that lane.

The vehicle and all systems should stabilize at the test speed prior to entering the test sections. This requires bringing the vehicle to the desired test speed at least 300 ft prior to the beginning of the test location.

Prior to reaching the test sections, activate all testing and recording equipment so that it is stabilized at the test speed.

Identify the beginning of the first test section by beginning the capture of data. This activation must be automatic. It is typically triggered by reflective tape on the pavement or attached to a traffic cone. This start point should be repeatable to less than 0.5 ft.

Maintain a smooth driving pattern with the height sensors centered in the wheel paths.

Compare the data being displayed from both wheel paths. They should track favorably, except for the short wavelength portion.

Identify any features along the test sections such as bridges, culverts, milepost or other pertinent information. Identify the end of the test length.

Repeat these data acquisition steps until three acceptable runs have been measured. See Calculations section below for criteria.

CALCULATIONS:

The following is a list of the calculations that will be completed for each tested 25 ft section and each run:

1. The average IRI for each section (averaging left and right wheel paths) on each run

2. The overall average IRI for each run

3. The coefficient of variation of the overall average IRIs; this value must be less than or equal to 3 percent for three runs for the data to be accepted.

All IRI values shall be computed in units of inches per mile and rounded to the nearest whole number.

REPORT:

A copy of the final roughness report for all sections tested shall be submitted to the Engineer and the Office of Materials Technology in accordance with the Special Provisions. The report shall contain the following:

1. An electronic copy, and if requested, a printed copy of the results from traversing one of the standardization sites as printed and saved by the test equipment. It shall include as header information, the same information as required for data collection on a project. This information is required with the first Quality Control data submission for the project, and for any future data submissions more than 60 days from the previously-submitted standardization test.

2. An electronic copy, and if requested, a printed copy of the test results for the pavement being measured as generated by the equipment performing the test. This report shall be for project level Quality Control (QC) data and shall include:

(a) Header information, including the equipment identification and approval date, site description (route, lane, limits, and direction), date and time of testing, equipment settings, the operator's name, software versions, filter lengths and test speed data (if not given for each section).

(b) The IRI values of each wheel path for each section of the 3 required runs.

(c) The exact length of each test section (typically 25 ft).

(d) The location of any section exceeding the prescribed IRI section limit

(e) Identification of data sections that represent any exempt areas which are to be excluded from pay adjustment calculations.

(f) A column identifying the accumulated distance or station number for each 25 ft. section.

An electronic copy, and if requested, hard copy data shall be submitted to the parties and locations and within the required time limits as specified in the Special Provisions. Electronic data shall be submitted either by e-mail, USB flash drive, CD-ROM, or DVD. Raw profile data (distance and elevation values) shall be saved by the testing vehicle's computer equipment and shall be available for all standardization and project QC data runs until the project is closed. However, the raw profile data does not need to be submitted unless specifically requested by the Administration.

Data Submittal. Submit all data to the Engineer and to the Office of Materials Technology (in electronic format) via one of the following:

(a) E-mail: ridespec@sha.state.md.us

(b) Delivered: **Office of Materials Technology**
7450 Traffic Drive
Hanover, Maryland 20176
Attention: Asphalt Paving QA Team Leader