INDIANA DEPARTMENT OF TRANSPORTATION
OFFICE OF MATERIALS MANAGEMENT

INERTIAL PROFILERS
ITM No. 917-17

1.0 SCOPE.

1.1 This test method covers the requirements for acceptance of smoothness with an inertial profiler, calibration and operation of an inertial profiler to evaluate the smoothness of HMA and PCC pavements, and the operator approval process for use of the inertial profiler equipment.

1.2 This ITM may involve hazardous materials, operations, and equipment and may not address all of the safety problems associated with the use of the test method. The user of the ITM is responsible for establishing appropriate safety and health practices and determining the applicability of regulatory limitations prior to use.

Note: Reporting global positioning system (GPS) data is optional between August 1, 2017 and December 31, 2018. Reporting GPS data will become mandatory January 1, 2019.

2.0 TERMINOLOGY. Definitions for terms and abbreviations shall be in accordance with the Department’s Standard Specifications, Section 101 and as follows.

2.1 Inertial Profiler. An inertial profiler is an INDOT accepted certified piece of equipment that utilizes line lasers and accelerometers to measure the road profile in both wheel paths simultaneously.

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

2.3 International Roughness Index (IRI). A statistic used to determine the amount of roughness in a measured longitudinal profile. The IRI is computed from a single longitudinal profile using a quarter-car simulation at 50 mph.

2.4 Line Laser. A line laser obtains a series of data points along a line, which is perpendicular to the travel direction, with the line typically being 4 in. long. A single, bridged elevation is computed from this data.

2.5 Longitudinal Profile. The vertical deviations of the pavement surface taken along a line in the direction of travel referenced to a horizontal datum.

2.6 Report Interval. The longitudinal distance between the outputs of a profile index value.
2.7 Sample Interval. The longitudinal distance between data capture points. The data include location height, and accelerometer values. These data points are combined to create one profile data point. These points, in turn, may be combined to create a final value in the reported profile.

2.8 Section. A section is a portion of a mainline travel lane paved in a given calendar year within a contract defined phase and a consistent typical section.

2.9 Area(s) of Localized Roughness (ALR). 25-foot continuous IRI ≥ 150.0 in/mi

3.0 SIGNIFICANCE AND USE. The IRI is used to assess pay factors for smoothness of HMA and PCCP pavements. Areas of pavement that are required to be corrected to comply with specification smoothness requirements are also determined.

4.0 EQUIPMENT.

4.1 Inertial Profiler. The inertial profiler shall meet the requirements and specifications of AASHTO M 328. The equipment shall be high-speed, full-size, motor vehicle mounted profilers. There shall be two line lasers, spaced at the location of the pavement wheelpaths, that are mounted on the vehicle to simultaneously measure the smoothness of the pavement. Wheelpaths are located parallel to the centerline of the pavement and approximately 3.0 ft either side of the center of a lane measured transversely. The inertial profiler software shall calculate and report the IRI in in./mile from the corresponding measured true profile and permit the operator to automatically trigger the start of data collection at the designated location. The inertial profiler shall provide the measured true profiles in ProVAL electronic text files following the format in AASHTO R 57. These profile data are necessary to evaluate profiler accuracy and repeatability and to verify the height and distance measurements.

4.2 GPS receiver can be used to measure pavement distance. GPS readings should conform to the World Geodetic System-84 (WGS-84) standard and include the following variables:

- Latitude (Lat): measure in decimal degrees to the sixth place
- Longitude (Lon): measure in decimal degrees to the sixth place
- Altitude (Alt): elevation or height above sea level to the nearest foot
- Heading (Hdg): bearing information in degrees
- Speed (Spd): speed information in miles per hour (mph)

5.0 CERTIFICATION PROCESS

5.1 General. The inertial profiler shall be calibrated on a Department test track prior to use on a project. Approval is valid for one year provided no equipment, operator, or software changes are made. Re-approval of the inertial profiler will be required if there are any
changes to the equipment, operator, or software. The Contractor’s operator(s) shall operate the equipment during the test track runs.

5.2 Longitudinal Distance Test

5.2.1 The distance measurement index (DMI) for longitudinal verification is done by navigating the inertial profiler over a measured test section of at least 528 ft. A proper lead-in distance for the vehicle to attain a constant speed before the start of the section and a safe stopping distance after the end of the section will be provided. The inertial profiler will be checked at the lower limit and upper limit of the manufacturer’s recommended operational speeds.

5.2.2 The starting and ending points of the test section will be clearly marked and measured. The length will be accurately measured to within 0.05 percent.

5.2.3 The tire and electronic warm-up of the inertial profiler shall be done in accordance with the manufacturer’s recommendations.

5.2.4 At least two auto-triggered runs between the lowest and highest test speeds of the inertial profiler shall be made. At the end of each run, the reading from the profiler’s DMI shall be recorded.

5.2.5 The absolute difference between the DMI readings and the known distance of the path tested for each run is required to be less than 0.15 percent to pass.

5.3 Block Test

5.3.1 Vertical height sensor block check tests are run after the inertial profiler has reached operational stability as specified by the manufacturer.

5.3.2 The vertical measurement standard shall be flat plates or gauge blocks of known thickness and low thermal expansion. The blocks will be measured with a device capable of measuring the thickness to the nearest 0.001 in. Three measurements will be taken on each side of the block and the average of the measurements will be determined. The blocks shall be marked with the known average thickness and the blocks certified as being accurate to within 0.001 in. As a minimum, a smooth base plate, a 0.25-in, 0.5-in and 1-in. gauge blocks are required. The owner of the inertial profiler shall furnish the base plates and blocks.

5.3.3 The block test is conducted on a relatively flat and level area. The inertial profiler shall not be moved in any way and under windy conditions the block test shall be performed indoors.
5.3.4 The smooth base plate is placed under the sensor of the inertial profiler and the height measurements are obtained by the system.

5.3.5 Each block is placed underneath the sensor on top of the base plate and ten height measurements are obtained by the system and averaged.

5.3.6 The absolute difference between the computed block thickness and the known average block thickness for the blocks shall be less than or equal to 0.01 in. to pass.

5.3.7 The operator of the profiler shall tabulate the measurements and record the measurements in a calibration log.

5.4 Bounce Test

5.4.1 Vertical sensor bounce check tests are run after the inertial profiler has reached operational stability as specified by the manufacturer.

5.4.2 The inertial profiler shall be placed on a surface as flat and level as possible.

5.4.3 A thin, smooth, flat, non-glossy material plate is centered under each sensor.

5.4.4 Using the equipment’s normal data collection software, a data collection run is done using a simulated travel speed at the midpoint of the manufacturer’s recommended operational speed range. (Note 1)

Note 1: The only difference between a bounce test and a normal data collection run is that there is an artificial longitudinal travel signal supplied and the vehicle is not actually traveling along the road. The bounce test utilizes the same data collection software and routines used during normal data collection.

5.4.5 The bounce test will require a profile collection run with a minimum simulated travel distance of 2184 ft.

5.4.6 The inertial profiler shall collect a minimum of 828 ft of static profile with the equipment as motionless as possible.

5.4.7 The sensor (s) shall be moved vertically for a total displacement of approximately 1 to 2 in. while keeping the sensor as close to perpendicular to the surface as possible during the movement (Note 2). This movement is required to be continued until a minimum of 528 ft of simulated longitudinal distance has been covered.
Note 2: A yardstick may be helpful until the operator is familiar with this procedure. The typical method for full-size, high-speed profilers is to push the mounting system (bumper) down an inch or so and let the vehicle suspension rebound to create the total vertical travel of 1 to 2 in. The typical method for lightweight, slow-speed profilers is to stand toward the center of the vehicle platform and move up and down such that all four corners of the vehicle suspension travel approximately 1 to 2 in. vertically.

5.4.8 After a minimum of 528 ft of bounce profile is collected, the inertial profiler shall collect an additional minimum of 828 ft of static profile.

5.4.9 The profiles shall be analyzed using the ProVAL software to compute the continuous IRI with a 528-ft base length for each profile collected. The first and last 300 ft of the profile shall not be included in the analysis as these distances are the lead-in and lead-out distances.

5.4.10 The static portion IRI results shall be less than 3 in./mile and the bounce portion IRI shall be less than 8 in./mile for the profiler to pass. The two static IRI portions shall be approximately the same. These requirements apply to each line sensor of the inertial profiler.

5.4.11 The operator of the inertial profiler shall tabulate the measurements and record the measurements in a calibration log.

5.5 Test Track Test

5.5.1 The test track shall be the same test section used for the DMI verification.

5.5.2 Test track approval will consist of two sets of five runs of the inertial profiler device.

5.5.3 Electronic copies of all road profiles collected on the two sets of five runs, including lead in and lead out distance, shall be submitted to the Department in ProVAL compatible format.

5.5.4 The Department will select up to four subsections within the two sets and establish reference values for IRI. All indices will be generated using ProVAL software.

5.5.5 For IRI, each of the five reported run values will be within 5.0 percent of the average of those values for each subsection to demonstrate repeatability of the equipment.

5.5.6 The average of the five reported run values shall be within 5 percent of the reference value or within 5 in./mile for each subsection, whichever is greater, to demonstrate reproducibility of the equipment.
5.5.7 The Department will allow one additional set of five runs if there is a problem with the verification of the inertial profiler.

6.0 DOCUMENTATION OF INERTIAL PROFILERS.

6.1 The Department will certify all inertial profilers or may allow certification from other DOTs that meet the requirements of this ITM.

6.2 The inertial profiler will be certified once per calendar year and prior to use on a contract in the same year.

6.3 A certificate of compliance will be issued to the Contractor for the inertial profiler being calibrated. The certification of compliance will include the following information:

6.3.1 Manufacturer Name

6.3.2 Model

6.3.3 Serial Number

6.3.4 Owner Identification

6.3.5 Inspection and Inactive Date

6.3.6 Calibration Settings

6.3.7 Software Version and Release

6.3.8 Operator Name

6.3.9 Filter Settings

6.3.10 Sampling Interval

6.4 Modifications to the inertial profiler will require a recertification in accordance with 5.0.

7.0 EQUIPMENT OPERATOR APPROVAL.

7.1 All operators of the inertial profilers shall demonstrate the ability to successfully perform the following on the equipment being certified on the Department test track:

7.1.1 Distance Measurement Instrument calibration
7.1.2 Static height sensor calibration

7.1.3 Bounce test

7.1.4 Road profiles in a ProVAL compatible electronic format

7.1.5 Exception indices using ProVAL software

7.1.6 Profile log sheet for profiles collected on the test track

7.2 Each operator will be given an approval letter indicating that the operator is approved to operate that particular inertial profiler. The operator approval is valid for one year.

7.3 Operators may be removed from approval for failure to follow the requirements for equipment operation, failure to perform site verification and testing as required, failure to produce accurate and timely roadway profiles, or any other failure to follow the requirements for surface smoothness measurements.

8.0 PROCEDURE FOR PROJECT OPERATION OF INERTIAL PROFILERS.

8.1 The Checklist for Verification of the Inertial Profiler (Appendix A) will be completed by the Engineer.

8.2 The inertial profiler shall be operated by a Contractor Technician that is approved by the Department.

8.2 The inertial profiler shall be certified and calibrated in accordance with sections 5.0 and 6.0. The Engineer may request a demonstration of distance, height, and bounce measurement accuracy and verify computer settings at any time. If the inertial profiler does not meet the verification requirements or there are equipment changes noted by the Engineer, the inertial profiler shall not be used on the project.

8.3 The certificate of compliance shall be presented to the Engineer prior to use of the inertial profiler on the project. The Engineer will check the distance, height, and bounce measurements of the inertial profiler on the project.

8.4 An agreed known distance measurement on the project will be checked in accordance with 5.2 to verify the DMI. The tolerance for the distance measurement will be 0.15 percent.

8.5 The height measurement using the block test will be checked in accordance with 5.3. The Contractor shall provide a caliper accurate to 0.001 in. for verifying the gauge block dimensions. The tolerance for the height measurement will be 0.01 in.
8.6 The bounce test will be done in accordance with 5.4. The IRI for the bounce test will be less than or equal to 8 in./mile.

8.7 The inertial profiler shall be operated in accordance with the following:

8.7.1 The roadway shall be cleaned of all debris and other loose material. Data shall be collected on a dry pavement.

8.7.2 The inertial profiler shall be operated at a relatively constant speed within the manufacturer’s recommended operational speed range. All data collected outside this speed range is not valid and re-measuring these pavement sections will be required.

8.7.3 A lead-in length of roadway of at least 300 ft. is required. Shorter lead-in sections may be considered if the physical constraints require a shorter length and other contract conditions make a shorter length acceptable.

8.7.4 Two longitudinal traces are required in the wheelpaths. The inertial profiler shall be operated 3.0 ± 0.5 ft from either side of the center of a lane measured transversely and parallel to the lane. Data shall be collected simultaneously with the sensors along the left and right wheelpaths.

8.7.5 Measurements shall be taken in the direction of traffic. If this is not practical and data is collected in the other direction, the direction will be noted in the report. For lanes utilized by traffic in either direction, the inertial profiler shall be operated in the direction of increasing station numbers.

8.7.6 Data shall be collected at the end of the contract paving season or staged as required by the Engineer.

8.7.7 The data shall be submitted to the Engineer in a format readable by ProVAL. The signed spreadsheet summary of smoothness corrections shall be submitted to the Engineer within 5 days after completion of IRI testing. (see APPENDIX B)

8.7.8 The areas exempt from measurement are as follows:

1. The first and last 50 ft within the entire construction paving limits
2. From 50 ft before through 50 ft after each bridge approach
3. From 50 ft before through 50 ft after each at-grade railroad crossing
4. From 50 ft before through 50 ft after each casting located within 4.0 ft measured laterally from the edge of lane.
9.0 REPORTS.

9.1 The Engineer will report the IRI for each section to the Contractor within seven calendar days from the date the ProVAL data was received.

9.2 The Engineer will notify the Contractor of the sections that do not comply with the smoothness specifications and require correction.

9.3 The ProVAL(s) data will be maintained with the final construction file.
APPENDIX - A

CHECKLIST FOR VERIFICATION OF INERTIAL PROFILERS

[ ] Profile Operator submitted a Certification Letter for the inertial profiler and the operator.

[ ] Engineer confirmed the operation of the inertial profiler equipment as follows:

<table>
<thead>
<tr>
<th>Verification Test</th>
<th>Actual</th>
<th>Measured</th>
<th>Difference</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height Sensor Test</td>
<td></td>
<td></td>
<td></td>
<td>≤ 0.01 in.</td>
</tr>
<tr>
<td>Bounce Test</td>
<td></td>
<td></td>
<td></td>
<td>&lt; 8 in./mi.</td>
</tr>
<tr>
<td>DMI calibration Test</td>
<td></td>
<td></td>
<td></td>
<td>&lt; 0.15 %</td>
</tr>
</tbody>
</table>

[ ] Engineer given copy of data to include raw data files, cropped data files, smoothness data, localized smoothness deficiencies and data collection log sheet

[ ] Engineer reviewed the procedure for correcting the profile of non-complying pavement in the Quality Control Plan

[ ] Post corrective action profile data received indicating that corrective action repaired violations.

Remarks:__________________________________________________________________________
__________________________________________________________________________________
__________________________________________________________________________________
__________________________________________________________________________________
__________________________________________________________________________________

Verified By:_________________________________________ Date:________________________
<table>
<thead>
<tr>
<th>Contract Number</th>
<th>Report Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date Measured</td>
<td>Smoothness Equation</td>
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<tr>
<td>Tested By</td>
<td>Posted Vehicle Speed</td>
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<tr>
<td>Direction</td>
<td></td>
</tr>
<tr>
<td>Lane Description</td>
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</tr>
<tr>
<td>Stationing</td>
<td>Section 1</td>
</tr>
<tr>
<td></td>
<td>Beginning</td>
</tr>
<tr>
<td></td>
<td>Ending</td>
</tr>
<tr>
<td>Beginning GPS</td>
<td></td>
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<tr>
<td>Ending GPS</td>
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<td>Grind</td>
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<td>Beginning Sta.</td>
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<tr>
<td>Ending Sta.</td>
<td></td>
</tr>
<tr>
<td>Segment Length(ft)</td>
<td></td>
</tr>
<tr>
<td>Final Smoothness (in/ft)</td>
<td></td>
</tr>
<tr>
<td>Segment Pay Adjustment</td>
<td></td>
</tr>
</tbody>
</table>

Total Areas of Localized Roughness Deduction

Data Entered By

Signature/Certification #

Avg. IRI

Total Distance (ft)