INDIANA DEPARTMENT OF TRANSPORTATION
DIVISION OF MATERIALS AND TESTS

INERTIAL PROFILERS
ITM No. 917-21

1.0 SCOPE.

1.1 This test method covers the requirements for acceptance of smoothness with an inertial profiler, certification, 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 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.

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 a Department-accepted certified piece of equipment that utilizes line lasers and accelerometers to measure the road profile in both wheel paths simultaneously.

2.2 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.

2.3 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.

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

2.5 Report Interval. The longitudinal distance between the outputs of a profile index value.

2.6 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.

2.7 Area(s) of Localized Roughness (ALR). Isolated areas that contribute disproportionately to the overall pavement roughness, identified as a 25-foot continuous IRI which exceeds the specified threshold.

3.0 SIGNIFICANCE AND USE. The IRI is used to assess pay factors for smoothness of HMA and PCCP pavements. ALR or overall smoothness deficiencies that are required to be corrected to comply with specification requirements are also determined. Certification of contract equipment and operators is required prior to project use.

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 vehicle wheel paths, that are mounted on the vehicle to simultaneously measure the smoothness of the pavement. 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. A GPS receiver shall 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 certified on a Department test track prior to use on a project. Certification is valid through the expiration date indicated by the Department provided no significant equipment or software changes are made. The Contractor's operator(s) shall operate the equipment during the test track runs. The profiler shall have a computer equipped with the current version of ProVAL in order to review profiles as necessary during certification.

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 shall be provided. The inertial profiler shall be checked at the lower limit and upper limit of the manufacturer's recommended operational speeds.

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

5.2.3 At least three runs at the lowest and highest test speeds of the inertial profiler shall be made; this results in at least six values. At the end of each run, the reading from the profiler's DMI shall be recorded.

5.2.4 The absolute difference between the DMI readings and the known distance of the path tested for each run shall be less than 0.15 percent.

5.2.5 The same runs may be used for verification of DMI accuracy as are used for testing accuracy and repeatability of the collected profile.

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 and marked on the blocks. This will be known as the average block thickness. As a minimum, a smooth base plate, a 0.25-in ,0.5-in and 1-in. gauge blocks are required.

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, non-glossy base plate is placed under the sensor 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 height measurements are obtained by the system.

5.3.6 The absolute difference between the profiler's measured block thickness and the known average block thickness for the blocks shall be less than or equal to 0.01 in.

5.3.7 The operator of the profiler shall tabulate the measurements and record the measurements in the checklist in Appendix A.

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 The smooth, non-glossy base 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 2,400 ft.

5.4.6 The inertial profiler shall collect a minimum of 900 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 600 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.

5.4.8 After a minimum of 600 ft of bounce profile is collected, the inertial profiler shall collect an additional minimum of 900 ft of static profile.

5.4.9 The profiles shall be analyzed using the current version of 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. The static portions before and after the bounce portion shall have approximately the same IRI. When viewing in ProVAL, the bounce portion of the IRI shall exhibit an increase followed by a decrease from baseline static IRI values while still remaining below the 8 in./mile threshold. 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 the checklist in Appendix A.

5.5 Test Track Test

5.5.1 The Department will select up to four test sections and establish reference values for IRI. All indices will be generated using ProVAL software.

5.5.2 The test track may be the same test section used for the DMI verification.

5.5.3 Five repeat runs of the candidate inertial profiler shall be made at each test speed on the designated profile trace of each test section in the prescribed direction of measurement. Make five runs at the maximum desired certification speed and five runs at the minimum desired certification speed.

5.5.4 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.

5.5.5 A cross correlation of 92% or higher shall be achieved for repeatability utilizing the ProVAL Certification module to analyze the 10 runs against each other.

5.5.6 A cross correlation of 90 % or higher shall be achieved for accuracy utilizing the ProVAL Certification module to analyze the 10 runs against the Department's reference profiler. In addition, no individual trace may vary from the Department's reference profile by more than 5%.

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 shall have a current certification prior to use on a contract in the same year. A list of certified equipment will be posted on the Department's website.

6.3 A Certificate will be issued to the Contractor for the inertial profiler being calibrated. The certificate 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 Expiration 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

7.0 EQUIPMENT OPERATOR APPROVAL.

7.1 All operators of inertial profilers shall register for and attend the Department's operator course on a triennial basis and pass the exam at the completion of the course. Completion of the course and passing results on the exam will be required prior to certification on the Department test track. All operators of inertial profilers shall also demonstrate the ability to successfully perform the following on the equipment being certified on the Department test track:

7.1.1 Longitudinal Distance test

7.1.2 Block test

7.1.3 Bounce test

7.2 Each operator will be given a certification indicating that the operator is approved to operate a certified inertial profiler. The operator certification is valid through the indicated expiration date. A list of certified operators will be posted on the Department's website.

7.3 Operators may be removed from approved status for failure to follow the requirements for equipment operation, failure to perform site verification and testing as required, failure to produce accurate 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. A Checklist from another Department contract signed by the Engineer within the previous two weeks will also be considered acceptable documentation.

8.2 The inertial profiler shall be operated by a certified operator.

8.3 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.

8.4 An agreed known distance measurement on the project will be checked in accordance with 5.2 to verify the DMI, with exception that two runs at lowest and highest speeds for a total of 4 runs shall be performed.

8.5 The block test shall be performed in accordance with 5.3.

8.6 The bounce test shall be performed in accordance with the manufacturer's recommendations utilizing the equipment's bounce test software. Record the results on the checklist in Appendix A.

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 dry pavement.

8.7.2 The inertial profiler shall be operated at a relatively constant speed within the manufacturer's recommended operational speed range. The operator shall not brake or stop during data collection which would introduce false bumps or dips into the data. All data collected outside this speed range or

with braking or stopping during collection is not valid and shall be re-measured.

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

8.7.4 Data shall be collected simultaneously with the sensors along the left and right wheel paths. Wheel paths are located parallel to the centerline of the pavement at 3.0 ± 0.5 ft either side of the center of a lane measured transversely.

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 shall 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 The data shall be submitted to the Engineer formatted in accordance with 8.7.7 and readable by ProVAL. Raw data files shall be submitted if requested.

8.7.7 The areas exempt from measurement are as follows:

- The first and last 50 ft within the entire construction paving limits
- From 50 ft before through 50 ft after each bridge and approach slab
- From 50 ft before through 50 ft after each at-grade railroad crossing
- From 10 ft before through 10 ft after each casting located within either wheel path.

8.8 Upon completion of measurement run, move the inertial profiler to a safe location, then save any relevant data to a file using an approved unfiltered electronic format. The file name should include the following:

- Route Number (I __, US __, SR __)
- Direction of Lane (NB, EB, SB, WB)
- Lane Number (Lane 1 is driver's left most lane increasing as lanes added to the right; other clear naming conventions are acceptable)
- Status of Run (Preliminary, Informational, Initial, Final After Correction)

9.0 REPORTS.

9.1 The Contractor shall submit formatted ProVAL files for each required profile

trace. The ProVAL files shall include smoothness IRI analysis for each 0.1-mile section of each profile as well as ALR analysis. Results of the smoothness analysis and ALR analysis shall be submitted as ProVAL reports to the Engineer.

9.2 The Engineer will review the submitted ProVAL files and ProVAL reports for each required profile trace utilizing Department guidelines. The Engineer will generate smoothness payment utilizing the Department spreadsheet and notify the Contractor of such results within 7 days or provide notification of issues with files that require modification. The IRI Field Guide and the IRI Pay adjustment Spreadsheet to be utilized for analysis can be found on the Department's website.

9.3 The Engineer will review the submitted ProVAL ALR report within 7 days and notify the Contractor of any discrepancies found or special considerations that may eliminate corrective grinding work. The Contractor may not proceed with corrective grinding work until 7 days after submission of ALR report. The IRI Field Guide for ALR to be utilized for analysis can be found on the Department's website.

9.4 The ProVAL data files and reports will be maintained with the final construction record.

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CHECKLIST FOR VERIFICATION OF INERTIAL PROFILERS

[ ] Engineer confirmed the operator and equipment are on the Department's certification list.

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

Verification Test	Actual	Measured	Difference	Tolerance
Block Test -L- Base Plate				≤ 0.01 in.
Block Test- L- 1 in Block				≤ 0.01 in.
Block Test -L- 2 in Block				≤ 0.01 in.
Block Test -R- Base Plate				≤ 0.01 in.
Block Test -R- 1 in Block				≤ 0.01 in.
Block Test- R- 2 in Block				≤ 0.01 in.
Bounce Test Dynamic		N/A	N/A	< 8 in./mi.
Bounce Test Static		N/A	N/A	< 3 in./mi.
Longitudinal Distance Test				< 0.15 %

[ ] 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:_____

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Verified By:_____ Date:_____