MATERIALS METHOD

SUBJECT: INERTIAL PROFILER CALIBRATION AND VERIFICATION

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I. SCOPE

This method includes procedures necessary to ensure that inertial profilers used on Department projects provide precise and accurate results. Verification procedures are provided to determine the precision and bias of measurements made with an inertial profiler. If the precision and bias are within the acceptable range, the profiler is considered verified. If the precision and bias are not within the acceptable range, the Contractor can adjust the profiler and repeat the process until the profiler is verified. Calibration procedures are included to ensure that the profiler’s three measurement devices remain in proper working order and calibration after the profiler has been verified.

II. BACKGROUND

Inertial profilers measure the pavement surface profile using a distance measurement transducer, noncontact vertical displacement transducer (usually infrared or laser), an accelerometer and a computer. The distance measurement transducer operates similarly to a car’s odometer, but more precisely. The noncontact vertical displacement transducer measures the distance between the device and the pavement surface at selected intervals. The accelerometer determines the inclination of the profiler as it ascends and descends hills, and corrects for any movement of the vertical displacement transducer relative to the ground caused by suspension travel. The computer collects and records all of the data from the other three devices, and uses the data to calculate the desired index to describe the pavement’s ride quality.

The Department uses international roughness index (IRI) to quantify ride quality of newly constructed HMA pavements. IRI uses a mathematical model to calculate the total vertical movement by one wheel of a vehicle as it travels over the pavement. IRI is reported as total vertical suspension travel divided by distance or meters per kilometer, m/km. More thorough definitions of IRI and related terms are given in the Department’s ride quality specification.

III. INFORMATION SOURCES

Personnel responsible for measuring profiles, calibrating profilers or verifying profilers must be fully aware of all specified requirements. The following is a list of reference documents.

AASHTO PP 43 Quantifying Roadway Roughness Using an Inertial Road Profiler with Laser Height Sensors
AASHTO PP50-02 An Inertial Profiler
AASHTO PP 51-02 Certification of Inertial Profiling Systems
AASHTO PP52-02 Operating Inertial Profilers and Evaluating Pavement Profiles
AASHTO PP53-02 A Pavement Ride Quality Specification when Measured Using Inertial Profiling Systems
ASTM E867 Terminology Relating to Vehicle-Pavement Systems
ASTM E950 Measuring the Longitudinal Profile of Traveled Surfaces with an Accelerometer Established Inertial Profiling Reference
ASTM E1364 Measuring Road Roughness by Static Level Method
ASTM E1926 Computing International Roughness Index of Roads from Longitudinal Profile Measurements


Sayers, Michael W. and Steven M. Karamihhas. The Little Book of Profiling - Basic Information about Measuring and Interpreting Road Profiles. University of Michigan Transportation Research Institute, 1998

AASHTO References are available from:

American Association of State Highway and Transportation Officials
444 North Capitol Street, NW
Suite 225
Washington, D.C. 20001
Phone: (202) 299-5400

ASTM references are available from:

American Society for Testing Materials
1916 Race Street
Philadelphia, PA 19103-1187
Phone (215) 299-5400

IV. DETAILS OF RESPONSIBILITY

A. CONTRACTOR

1. Verification Testing

$ Schedule verification testing for equipment with the Materials Bureau or Verification Agency.
$ Successfully verify at least one inertial profiler and operator prior to start of work.
$ Provide a list of qualified profile operators to Engineer before beginning QC testing.
$ Provide Engineer with verification letter(s) and BR2s form(s) for inertial profiler and operator(s).
2. Calibration
   
   $ Perform Daily Calibration Procedures.
   $ Record Measurements and Calibration settings in a Calibration Log Book.

3. Daily Control Testing
   
   $ Select location for control testing.
   $ Request approval of control section location from the Engineer.
   $ Establish control section location and profile.
   $ Perform daily control testing.

B. DEPARTMENT

1. Verification Testing
   
   $ Establish verification site.
   $ Coordinate verification testing schedule.
   $ Perform all necessary calculations.
   $ Complete the BR-2s form.
   $ Transmit verification letters to Contractors as necessary.

2. Calibration
   
   $ Witness daily calibration testing.

3. Daily Control Testing
   
   $ Approve control section location.
   $ Witness daily control testing.
   $ Develop and maintain control chart.
   $ Notify contractor if control chart plots extend beyond acceptable limits.

V. CALIBRATION PROCEDURES

The Contractor calibrates each profiler used on a Department project according to the procedures of this section. Calibration procedures are witnessed by a Department representative. Calibrations are performed according to the procedures of this section and manufacturer’s written instructions.

A. CALIBRATION FREQUENCY

Perform all calibration at the start of the day, prior to performing the Daily Control Testing. Calibrate all transducers at the following frequencies:

$ Once per testing day
$ When a daily control test indicates the profiler is out of calibration
$ Whenever any of the following actions are taken.
   $ tire replacement
$ profiler indicates an unreliable signal from a transducer
$ inspection, resoldering or replacement of electrical connectors
$ cleaning components
$ normal voltage adjustments as required by the manufacturer setting software parameters or scale factors as required by the manufacturer

B. CALIBRATION LOG BOOK

The profiler operator shall keep a log book of all calibration activities with the profiler at all times. For each calibration procedure described below, record the following information.
- Date of Calibration
- Instrument calibrated
- Measurement Results
- Adjustments, if any, made to equipment based on results

C. DISTANCE MEASUREMENT INSTRUMENT (DMI) CALIBRATION

$ Calibrate the distance measurement using the reference line for daily control testing, see section VII. A. Establish Control Section.
$ Perform all measurements at the same speed used for QC testing.
$ To pass the DMI Calibration Check the measured distance must be within ± 0.300 m of the actual distance, for one measurement.
$ Calibrate and adjust the DMI according to manufacturer’s written instructions.
$ Manufacturers may require a smaller calibration tolerance.

D. VERTICAL DISPLACEMENT INSTRUMENT (VDI) CALIBRATION

$ This procedure requires a metal base plate and metal plates of thicknesses 6.35 mm, 12.7 mm and 25.4 mm.
$ Each plate must be stamped with its nominal thickness.
$ The contractor will provide certification that the thickness of each metal plate is ± 0.3 mm of its nominal thickness.
$ Calibrate the Vertical displacement device on a flat level surface.
$ During windy conditions this procedure may need to be performed indoors.
$ The base plate and each successive block is placed under the VDI.
$ The VDI makes and records ten measurements of the height of the base plate and each block.
$ Calculate the average VDI measurement on the base plate; BP_{avg}.
$ Calculate the difference between BP_{avg} and each individual measurement on each block. These are the measured thicknesses of each block.
$ Calculate the absolute difference between each measured block thickness and the known thickness of the respective block. These are the errors for each block thickness measurement.
$ To pass the VDI calibration check the average error for the measurements on each block must be = 0.25 mm.
$ Calibrate and adjust the VDI according to manufacturer’s written instructions.
E. ACCELEROMETER CALIBRATION

$ Accelerometers must be properly calibrated and in good working order.
$ Follow manufacturer’s instructions to calibrate the accelerometer.
$ This procedure may include both a static and dynamic test.

VI. DAILY CONTROL TESTING

Daily control testing is performed to ensure that the inertial profiler is providing consistent results from day to day. Daily control testing is performed on a control section that is, when possible, maintained for the project’s duration. The test results are charted on a control chart. Statistical methods are employed to determine if the profiler is providing consistent results. Daily control testing must be witnessed by a Department representative.

Control sections may be located on a driving lane, ramp, or shoulder. Any section of pavement from which traffic can be removed each day, may be used as a control section. If a shoulder is used the cross slope may require VMI calibrations be performed at a different location. Also, the shoulder cross slope increases the risk of operator induced error, if the vehicle’s path varies from the reference line.

A. ESTABLISH CONTROL SECTION

$ Select an area on or near the project site that can facilitate testing as described in this section.
$ Submit the selected location to the Engineer for approval at least 24 hours prior to the start of quality control testing.
$ Establish a reference line 200.00 m long, with a lead-in section of at least 50 m and a safe acceleration and deceleration areas, according to ASTM E1364. Lead-in and acceleration areas may overlap.
$ Clearly mark the reference line’s, start and end points, and maintain the markings for the project’s duration. Operator induced error may be minimized by marking the reference line or using pavement lane markings to designate the reference line.

B. DAILY CONTROL TESTING PROCEDURE

$ Perform Daily Control Testing each day after performing calibration procedures and prior to performing any QC testing.
$ Perform all testing according to Test Method NY 402-01 F.
$ Make all measurements in the same direction.
$ On the first day of DCT for each profiler, perform 10 IRI measurements of the control section.
  $ These measurements may be made on the first day of QC testing.
  $ The maximum allowable IRI for a control section is 1.50 m/km.
  $ The maximum standard deviation of the 10 measurements is 0.05 m/km.
$ On all subsequent days of DCT perform one measurement of the control.
$ Record all appropriate information on form BR5s. A blank copy of the form is located in Appendix B. The page may be photocopied for field use.

C. CONTROL CHARTS

1. Establishing and Maintaining Control Charts

The Department will establish and maintain a control chart using Control Chart Software distributed by the Materials Bureau and the data entered on form BR5s. The control chart software is intended to detect out-of-tolerance measurements which require machine calibration, adjustment or repair.

The project staff enters the necessary information into the control chart software. The control chart software tabulates and plots each measurement (in black), where the ‘y’ axis is IRI and the ‘x’ axis is the run number. On the same chart, the upper and lower control limits are plotted as points corresponding to ± 5.7% of the previous measurement (in red) and ± 10.0% of the running average for all measurements (in green).

2. Responding to Out-of-Tolerance Measurements

If a DCT measurement (black) is plotted outside of the control limits (above or below a green or red line) follow these procedures.

- Have the operator repeat the calibration procedures.
- Perform a repeat measurement and enter the result into the control chart software in place of the original out-of-tolerance measurement. If any of the initial 10 measurements plot out-of-tolerance, all 10 must be repeated.
- Enter the repeat measurement result(s) into the control chart software in place of the original out-of-tolerance result(s).
  • If the repeat measurement (or all 10 if during initial testing) plots within the control limits, QC testing may proceed.
  • If the repeat measurement (or any one of the 10 if during initial testing) is also out-of-tolerance, the equipment will be considered unverified.
    • The Engineer will notify the Contractor, Regional Materials Engineer and Materials Bureau that the equipment is considered unverified.
    • QC testing can not continue with the equipment until it has successfully completed verification testing.
VII. VERIFICATION PROCEDURES

The procedures of this section will be used to verify the calibration of inertial profilers and the performance of the equipment operators as part of the Department's Independent Assurance Sampling and Testing Program.

The Department will establish and survey each verification site. The Director, Materials Bureau may approve sites that are established and surveyed by outside agencies. The Contractor shall perform separate verification procedures for each inertial profiler and operator.

The Department or approved verifying agency will perform all calculations required by this section.

A. VERIFICATION FREQUENCY

1. Inertial Profilers

Verify each profiler, prior to use on Department projects. Verification is valid for the remainder of the calendar year in which it is issued. Verification will be revoked under any of the following circumstances.

- If daily control testing indicates that verification is necessary according to the procedures of Section VI. C. 2. Responding to Out-of-Tolerance Measurements.
- If any of the following hardware items are repaired or replaced:
  - profiler drive train or suspension
  - accelerometer and associated hardware
  - non-contact vertical displacement measuring device
  - distance measurement transducer
  - any printed circuit board necessary for the collection of raw sensor data or processing the inertial profiles and IRI

2. Operators

Each operator must successfully complete verification testing once per calendar year.

B. ESTABLISH SITE

The Department or an approved verifying agency will establish a verification site meeting the requirements of this section. Sites will consist of the following sections in sequential order: acceleration, stabilization, data collection, deceleration. The requirements for each section are given below. An area for parking of transport vehicles and an area where repairs and adjustments can be made to the profilers must be provided near the verification site.
1. Acceleration Section
   $\quad$ Long enough to provide safe acceleration to testing speeds
   $\quad$ May contain curves of sufficient radius to allow safe operation of the profilers
   $\quad$ Of similar ride quality as data collection section

2. Stabilization Section
   $\quad$ At least 45 m long.
   $\quad$ Straight for entire length
   $\quad$ Of similar ride quality as data collection section

   **NOTE:** This section is required to allow measurements to be taken ahead of data collection area for filtering purposes.

3. Data Collection Section
   $\quad$ Straight for a distance of 160.00 m.
   $\quad$ Minimum IRI = 0.55 m/km
   $\quad$ Maximum IRI = 1.10 m/km

4. Deceleration Section
   $\quad$ Long enough to provide safe deceleration from testing speeds
   $\quad$ May contain curves of sufficient radius to allow safe operation of the profilers
   $\quad$ Of similar ride quality as data collection section

C. **ESTABLISH ROD-AND-LEVEL PROFILE**
   $\quad$ The Department or approved verifying agency will establish a rod-and-level survey of the site for comparison with profiler measured profiles.
   $\quad$ Establish a 160.00 m long reference line in each wheelpath of the data collection section to ASTM E1364. The two lines of reference must be 1.83 m apart and parallel.
   $\quad$ Mark each reference line with a 50 mm wide paint spot every 0.1 m. Take care to center each paint mark at the proper location. The marked locations will act as data collection points for measuring the rod-and-level profile and verification testing. When possible, more permanent and precise methods of marking the reference line data points should be used, such as steel pins or nails driven into the pavement until flush with the surface.
   $\quad$ Determine and record the elevation at each marked location according to ASTM E1364 for Class 1 profilers.
   $\quad$ The rod-and-level profile may be measured using automated equipment, approved by the Director, Materials Bureau, that collects data at an interval different from the automated equipment, provided the following additional steps are taken.
   $\quad$ Measure the profile three times with the automated equipment.
Check the equipment measurements with a rod and level along each reference line at least 10 times in locations that are multiples of the collection interval of the equipment. For example if a device has a sampling interval of 0.25 m it can be checked with a rod and level every 1 m, 10 m or 25 m.

Use the measured elevations to interpolate the relative elevations at the originally marked interval for each of the three profiles. Maintain a record of these interpolated profiles.

Calculate the average relative elevation at each of the originally marked data collection points. These average relative elevations will be the rod-and-level profile.

The Department will use RoadRuf software, or equivalent, to calculate the IRI, according to the quarter car model, for each reference line. Alternative software can be used to calculate IRI with the Director, Materials Bureau’s written approval.

Maintain the reference line data collection point markers for the entire paving season.

Repeat the survey at the start of each construction season prior to performing any verification testing.

If the pavement profile is altered at any time after the initial annual survey, perform a new survey and recalculate the IRI for each reference line.

**D. COLLECT PROFILE DATA FOR ANALYSIS**

The profiler operator is responsible for collecting all required data and providing that data to the Department or approved verifying agency.

Set the profiler data reporting interval to 0.05 m.

Perform 10 measurements of IRI along the reference line, according to Test Method NY 402-1 F.

Two measurements may be aborted or discarded prior to submission at the operator’s discretion.

If more than two measurements are aborted or discarded, discard all of the measurements and perform 10 new measurements.

**E. REPEATABILITY AND ACCURACY OF RELATIVE ELEVATION MEASUREMENTS**

1. **Repeatability of Relative Elevation Measurements.**

   Calculate the standard deviation for the 10 elevation measurements made at each sample location (every 0.05 m).

   Calculate the average of the standard deviations from all sample locations.

   To pass the Repeatability of Relative Elevation Measurements Test the average standard deviation must be ≤ 1.0 mm.

   If the average absolute difference is > 1.0 mm, the profiler owner must calibrate or repair the equipment as needed and repeat the verification procedure.
2. Accuracy of Relative Elevation Measurements

a. Establish Filtered Rod-and-Level Profile

$ For this procedure the Profiler Owner must provide the Department with an IBM compatible executable version of the filter used by the profiler to establish the measured elevations.

$ The executable file must be capable of outputing the results in ASCII text or an .ERD file format.

$ Filter the rod-and-level profile using the provided program.

$ After filtering, calculate the average relative elevation at each data collection point.

b. Establish the Test Profile

$ Synchronize the 10 profiles measured by the profiler such that each reported elevation corresponds to a data collection point from the filtered rod-and-level profile (every 0.25 m).

$ Establish the test profile by computing the average relative elevation at each data collection point.

c. Calculate $U_1$ and $U_2$ Statistics

$ Calculate the difference between the filtered rod and level profile and the test profile, point by point.

$ The average of these differences is $u_1$.

$ The average of the absolute values of these differences is $u_2$.

$ To pass the Accuracy of Relative Elevation Measurements Test:

$ $u_1$ must be within ± 0.5 mm

$ $u_2$ must be = 1.5 mm

2. Repeatability and Accuracy of Calculated IRI

a. Repeatability of Calculated IRI

$ The profiler operator shall calculate the IRI of the site using each of the 10 profiler measurements and the profiler software.

$ Calculate the standard deviation of the 10 IRI measurements.

$ To pass the Precision of Calculated IRI Test, the standard deviation must be ≤ 0.05 m/km.

$ If the standard deviation is > 0.05 m/km, the profiler owner must calibrate or repair the equipment as needed and repeat the verification procedure.

b. Accuracy of Calculated IRI

$ Calculate the average IRI for the 10 profiler measurements.

$ Calculate the IRI of the rod-and-level profile (unfiltered) using ProVAL© or an equivalent program approved by the Director, Materials Bureau.

$ Calculate the absolute difference between the average IRI measured by the profiler and the average IRI measured by rod-and-level.
To pass the Accuracy of Calculated IRI Test, the absolute difference must be $= 0.10 \text{m/km}$.

If the absolute difference is not $< 0.10 \text{m/km}$, the profiler owner must calibrate or repair the equipment as needed and repeat the verification procedure.

**F. VERIFICATION REPORT**

Immediately after each measurement the profiler operator will provide all information required by Test Method NY 402-1 F and this Materials Method to the Department personnel or approved verifying agency.

The Department or approved verifying agency will complete Form BR 2s. A blank copy of BR 2s is located in Appendix B.

**G. VERIFIED STATUS**

Profilers and operators that successfully pass all four tests described above will be granted verified status. When verified, the Director, Materials Bureau, or Approved Verifying Agency will notify the equipment owner and operator in writing and provide a signed copy of the BR 2s. Verification of an inertial profiler is valid for the remainder of the calendar year in which verified status is achieved. Verification of an operator is valid for one year on any inertial profiler of the same make and model as the one used in the verification procedures.

**IX. CONTACT INFORMATION**

Requests for information or technical assistance related to this Materials Method should be directed to the Field Engineering 2 office of the Materials Bureau at the following address and phone number.

Field Engineering 2  
Materials Bureau  
1220 Washington Ave.  
Bldg. 7A, Rm 230  
Albany, NY 12232-0861  
phone: (518) 457-4582  
fax: (518) 457-8171
Appendix A

Example Daily Control Chart

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Appendix B

Blank Forms
## EVALUATION DATA

### RELATIVE ELEVATION MEASUREMENTS

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### PROFILER IRI RESULTS

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### CALCULATED IRI COMPARISON

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The Evaluation Personnel Signature, below, signifies that the profiler and operator meet all requirements of Materials Method 24.1 Section VII. Verification Procedures.

_________________________ _________________________________ __________________________
Evaluation Personnel Signature    Date
____________________________________________________________________________________
Print Name    Title
# Inertial Profiler Daily Control Testing

## Profiler Information

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## Daily Control Testing Results

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