

Tex-1001-S, Operating Inertial Profilers and Evaluating Pavement Profiles

Overview

Effective dates: August 2002 – October 2004.

Test Method Tex-1001-S covers use of an inertial profiler to implement Special Specifications 5440 and 5880 for ride quality measurements using Surface Test Type B for quality assurance (QA) testing. The inertial profiler apparatus is described as well as major and minor repairs and adjustments. Verification of calibration procedures are covered. Procedures for collecting inertial profile data on paving projects are outlined. The required test data description and data format are prescribed and examples are given. The methodology used to detect areas of localized roughness is provided and referenced. Inertial profiler and inertial profiler operator certification are detailed.

This test method describes the procedure for operating and verifying calibration of an inertial profiler. This test method is meant to be performed as a Quality Assurance (QA) test for use with the appropriate smoothness specification for paving operations. It is not meant to be required as a Quality Control (QC) procedure to monitor daily paving operations; however, this method is recommended when inertial profilers are used for QC testing. It also provides:

- ◆ a methodology for inertial profiler certification as well as specified data format, and
- ◆ a methodology for inertial profiler operator certification.

The inertial profile data files obtained following this test method will be used as input to the PROVIEW software program. The PROVIEW software will perform ride summary calculation on the input data and report the bonus and penalties as prescribed by Special Specifications 5440 and 5880. The PROVIEW software will also detect the location and magnitude of any areas of localized roughness contained in the paving project.

Apparatus

An inertial profiling system consisting of a minimum of the following components:

- ◆ housing vehicle capable of traveling at speeds of a minimum of 12 mph while collecting pavement profile data
- ◆ distance measuring subsystem that is accurate to within 2 feet per 528 feet of distance traveled
- ◆ inertial referencing subsystem capable of measuring the movement of the housing vehicle as it traverses the pavement under test
- ◆ non-contact height measurement subsystem capable of measuring the height from the mounted sensor face to the surface of the pavement under test
- ◆ inertial profiler, with the following:

- hardware and software capable of producing and storing inertial profiles by combining the data from the inertial referencing subsystem, the distance subsystem, and height measurement subsystem
- capability of measuring and storing profile elevations at 6-inch intervals or less. It will be capable of outputting these elevations in the format described in 'Test Data Description and Format.'
- capability of summarizing (computing) the profile elevation data into summary roughness statistics over a section length equal to 0.1 mile (summary roughness statistic prescribed is the International Roughness Index [IRI] for each longitudinal path profiled)
- such design to allow field calibration and verification of calibration for the distance measurement (horizontal) subsystem and the height measurement (vertical) subsystem described in 'Inertial Profiler Certification.'
- certified for use in Texas. The certification procedure is documented in 'Inertial Profiler Certification.'

NOTE: For consistent pavement profile determination, maintain air pressure on the wheels of the housing vehicle according to the manufacturer's specification. The housing vehicle and all system components will be in good repair and proven to be within the manufacturer's specifications. The operator of the inertial profiler shall have all tools and components necessary to adjust and operate the inertial profiler according to the manufacturer's instructions.

Repair and Adjustment of Inertial Profilers

Major component repairs or replacement to an inertial profiler that would cause the recertification of the equipment include but are not limited to the following:

- ◆ the accelerometer and its associated hardware
- ◆ the non-contact height sensor and its associated hardware
- ◆ any printed circuit board necessary for the collection of raw sensor data or the processing of the inertial profiles and IRI.

The operator of the inertial profiler will be allowed to make minor adjustments to the equipment without having to complete the recertification process as long as the adjustments allow the equipment to fulfill the following verification of calibration process.

Minor adjustments to the system include but are not limited to the following:

- ◆ inspecting, resoldering, or replacing connectors
- ◆ cleaning components, normal adjustments to voltage levels as required by the manufacturer
- ◆ setting software parameters and/or scale factors as required by the manufacturer.

Verifying Calibration

The following verification procedure is required for QA testing and is recommended when an inertial profiler is to be used as a QC instrument on a daily basis.

Standards

- ◆ Horizontal
 - The horizontal or longitudinal calibration standard shall be a straight roadway test section of 528 feet in length.
 - Using a steel measurement tape or electronic measuring device, measure this length accurately to within 1 foot.
- ◆ Vertical
 - The vertical measurement standard shall be a flat plate(s) of known thickness(es).
 - Mark the plate(s) with the known thickness(es).
 - As a minimum, test a base plate and a 1-inch measurement plate.
 - Certify the measurement plate thickness accurate to within 0.001 inch.

Procedure

- ◆ Frequency of Verifying Calibration
 - Perform the horizontal and vertical verification of calibration of the inertial profiler prior to use on each paving project according to the manufacturer's recommendations.
 - Check the tire air pressure on the wheels of the housing vehicle and maintain according to the manufacturer's recommendations.
 - Maintain a log, to be kept with the inertial profiler, to provide a verification of calibration history.
- ◆ Horizontal Verification of Calibration
 - Perform the horizontal (longitudinal) verification of calibration by navigating the inertial profiler over a measured test section of 528 feet in length.
 - The inertial profiler's distance measuring subsystem must measure the length of the test section to within 2 feet of its actual length.
 - Adjust the inertial profiler's distance measurement subsystem according to the manufacturer's guidelines.
 - Failure to meet the specified tolerance will require re-calibration by the contractor and re-verification as described under 'Verifying Calibration.'
- ◆ Vertical Verification of Calibration
 - Perform the vertical verification of calibration on a flat and level area using the flat plate of known thickness. Windy conditions may necessitate that the test be performed indoors.

- Place the base plate under the inertial profiler’s non-contact height sensor. The inertial profiler’s height measurement subsystem takes a height measurement. This measurement will be used as the reference height for subsequent measurements.
 - Place a 1-inch plate on top of the reference plate below the non-contact sensor. The inertial profiler’s height measurement subsystem measures this displacement to within 0.01 inch of the 1-inch plate’s thickness.
 - Remove the 1-inch plate and verify that the inertial profiler’s height measurement system returns to the original reference plate’s displacement to within 0.01-inch. Failure to meet the specified tolerance will require re-calibration. If the re-calibration requires major repair as noted under 'Repair and Adjustment of Inertial Profilers,' then the profiler shall be re-certified at the Ride/Rut Facility located at the Riverside Campus of Texas A&M University. The certification procedure is covered under ‘Inertial Profiler Certification.’ If minor repairs are required, as indicated under ‘Repair and Adjustment of Inertial Profilers,’ it shall be re-verified.
- ◆ **Quality Control**
- When a profilograph is used for quality control purposes, the zero inch blanking band PI values (in inches/mile) can be converted into estimated IRI values (in inches/mile) using the following equation.

$$IRI = \frac{4.445 \times PI}{1 + (0.02073 \times PI)}$$

Procedure

The following table outlines the steps for measuring the pavement profile.

Measuring Pavement Profile for QA Purposes	
Step	Action
1	Locate and mark all “leave-out” sections as directed by the Engineer. “Leave-out” sections will not be evaluated for the payment of bonuses or penalties. “Leave-out” sections will include any additional pavement length as prescribed in the smoothness specification including the first and last 25 feet of the paving project.
2	Clean the roadway path to be measured of all debris and other loose material.
3	<ol style="list-style-type: none"> 1. When measuring the pavement profile, operate the inertial profiler at a constant speed of 12 mph or greater. 2. Failure to maintain this minimum speed will cause the inertial referencing subsystem to “droop,” hence the pavement profile elevations will not be usable. 3. Re-measure any pavement segment where the average operational speed per 0.1 mile is less than 12 mph.
4	<p>A pre-section length of roadway is required to “settle” the inertial profiler’s filters.</p> <ol style="list-style-type: none"> 4. This pre-section shall be at least 200 feet in length and located immediately before the section of pavement under test. 5. Take the inertial profile measurements on two longitudinal lines in each travel lane. <ol style="list-style-type: none"> 1. These longitudinal lines are to be in the wheel paths of each pavement travel lane that will be profiled and are 69 inches apart. 2. The profile location will normally lie three (3) feet from and parallel to the approximate location of the pavement lane edge.

Measuring Pavement Profile for QA Purposes	
Step	Action
	3. If the inertial profiler is capable of measuring profiles from two longitudinal wheel paths during a single pass, then the wheel path spacing shall be 69 inches.
5	Collect measurements in the direction of traffic. When using an inertial profiler that collects a single wheel path per pass, take care to insure that the measurements from each wheel path in a travel lane start and stop at the same longitudinal locations.
6	Optional: Marking “leave-out” sections. 6. Place event markers in the elevation data that correspond to the location of each “leave-out” section during the measurement process, if the inertial profiler has this capability. 7. Refer to the optional ‘Test Data Description and Format’ section of this test method for proper location of event markers in the data file.
7	Data Collection (QA data collection is meant to be performed at the end of the paving operation or staged as prescribed by the Engineer). ◆ Collect pavement profiles on a project in a single data file per travel lane when both wheel paths are measured during a single pass and the inertial profiler is capable of producing the optional data format, or; ◆ Collect pavement profiles on a project in 2 data files per travel lane when a single wheel path is measured during a single pass and the inertial profiler is capable of producing the optional data format, or; ◆ Collect pavement profiles on a project in multiple data files per travel lane when the inertial profiler is NOT capable of producing the optional data format. ◆ Submit to the Engineer a table that identifies the lane(s), wheel path(s), and distance location(s) tested for each file created during the QA testing.
8	Present the profile elevation data to the Engineer in an electronic format (on floppy disk or CD) with a file format as described in 'Test Data Description and Format' or the optional data format of this test method. NOTE: The Engineer will use TxDOT software to calculate the IRI values and associated pay factors.
9	The Engineer will: 8. compute a summary roughness statistic for each 0.1-mile pavement segment. This roughness statistic is the IRI. 9. calculate and record the IRI from each longitudinal line profiled for a pavement travel lane. The payment schedule will be based on the average IRI calculated from both wheel paths in a travel lane. 10. calculate and record the locations of areas of localized roughness.

NOTE: Calculate the pay adjustment for segment lengths less than 0.1-mile and greater than 50 feet as follows:

- ◆ suppose that the length of the short section is 0.075 miles;
- ◆ measured IRI = 37 in./mile; and
- ◆ the pay is \$460 for a full 0.1-mile section with an IRI = 37 in./mile:

$$Pay\ Adjustment = \$460 \times \left(\frac{0.075}{0.10} \right) = \$345$$

Test Data Description and Format

Test data must be reported in mils and in an ASCII file. This will permit TxDOT to directly input profile data, collected with any inertial profiler, into its data reduction program for QA testing. Each record will be separated by a carriage return and line feed (CRLF). A comma will separate each header and data entry in a record. The required format of the data file is illustrated in the 'Example Profile Data File' and in the 'Optional Example Profile Data File' and explained as follows:

- ◆ First Record. The first record will consist of the following items, each separated by a comma, and only a comma, i.e., no blanks or spaces between items in the record:
 - The first item is the identifier for the record. This shall be written as HEAD3 in the data file as illustrated in the 'Example Profile Data File.'
 - Date of profile measurement in mmddyyyy format where mm is the numeric designation for the month, dd is the day, and yyyy is the year. Zero-fill the first digit for the months of January to September (i.e., 01 to 09). Likewise, zero-fill the first digit for days 01 to 09 of a given month.
 - District where profile measurements were made in ## format. Note that ## is the two digit numeric designation for the given district (see district). Zero-fill the first digit for Districts 01 to 09.
 - County number in #### format. Zero-fill the leading digits as necessary.
 - Highway name in \$\$#####\$ format where "\$" represents a character descriptor following PMIS convention. The first two characters designate the highway system, e.g., interstate, US highway, state highway, farm-to-market, etc. These characters are always filled in, and may be any of the letters A to Z, written in upper case. No blanks or spaces are allowed in the highway system designation. Zero-fill leading digits as necessary in the highway name. The last character is a suffix. It is usually blank or N, S, E, or W (north, south, east, or west); for Park Roads it can be blank or A-Z; for Business Routes it can be A-Z (except I and O).
 - Beginning reference marker of the measurement in #####\$±##.### format. Zero-fill leading entries in the first four digits of the beginning reference marker as necessary. Likewise, zero-fill the first digit following the + or – sign as necessary. The character following the first four digits is a suffix. It may be any of the letters A to Z, written in upper case, or a blank (space). Following the suffix is a + or – sign, indicating the relative direction of the offset, in miles, from the beginning reference marker. The offset is specified by the number following the + or – sign. As necessary, zero-fill trailing entries to the right of the decimal point in the offset, e.g., 0521 +05.300, not 0521 +05.3. Reference marker numbers range from 0010 to 0999 (the fourth digit is provided to accommodate future expansion of the highway system).
 - Lane tested in \$# format following PMIS convention (see 'PMIS Lane Designations'). The first character designates the roadbed, and may be any of the letters K, R, L, A, and X, written in upper case. It cannot be a blank or space. The digit following the first character may take on a value from 0 to 9, and must be filled in.

- Additional Notes: The Engineer can run a ‘List of Sections to be Rated’ report in PMIS to get the correct highway and reference marker designations to be used for testing. The resulting profile data, once converted to PMIS format, can be stored in PMIS using Rating Cycle = ‘C’ (for Contractor).
- ◆ Second Record. The second record will have the following variables, each separated by a comma, and only a comma, with no blanks or spaces between variables:
 - The first variable is the identifier for the record. This shall be written as CMET3 in the data file as illustrated in the 'Example Profile Data File.'
 - Model designation of the lightweight profiler used for testing. This variable or item in the record may consist of 1 to 20 characters. Allowed entries are the letters A to Z, numbers 0 to 9, +, -, #, \$, &, colon, dash, period, asterisk, tilde, underscore, forward slash, left parenthesis or bracket, and right parenthesis or bracket. Letters may be entered in upper or lower case. Blanks are not allowed.
 - The third, fourth, fifth, and sixth items in the record are reserved for the use of the profile manufacturer or the contractor. Each of these items may consist of 1 to 20 characters. Allowed entries are the same as those identified for the model designation described above. Note that if these items are not specified, the comma delimiting each item must still appear in the record as illustrated in the 'Example Profile Data File.'
 - The seventh item in the record is the certification code for the given profiler. It is a string of 1 to 20 characters that is issued by the testing agency upon passing the Inertial Profiler Certification testing. Allowed entries are the same as those identified for the model designation described above.
 - The last item in the record is the certification date in mmddyyyy format. Zero-fill the first digit for the months of January to September (i.e., 01 to 09). Likewise, zero-fill the first digit for days 01 to 09 of a given month.
- ◆ Third Record. The third record will have the following variables, each separated by a comma, and only a comma, with no blanks or spaces between variables
 - Manufacturer of the lightweight profiler. This variable or item in the record may consist of 1 to 20 characters. Allowed entries are the same as those identified for the model designation specified in the second record of the data file.
 - The unit of elevation used to report profile. Under the current TxDOT practice, this shall be entered as mil (0.001 in.), as shown in the example profile data file at the end of this section. All three letters must be entered in lower case.
 - The wheel path measured designated as L for left, R for right, or LR for dual wheel path profilers, with no blanks or spaces separating the L and R. Note that L and R are relative to the direction of traffic on the lane surveyed. For dual wheel path profilers, the order in which the relative elevations are reported shall be left–right. Thus, for dual wheel path profilers, the wheel paths are always designated as LR.
 - The reporting interval (distance between successive relative elevation measurements) in inches or meters.
 - The unit of the reporting interval item: either i = inch or m = meters. The unit must be written in lower case.

- ◆ Fourth and Fifth Records. The fourth and fifth records are reserved for text comments. Each record can be up to 80 characters long.

The first five records of the ASCII data file are thus header cards. Following the fifth header record, the relative measurements at each longitudinal location are reported. For profilers that measure only one wheel path in a given run, there shall be a column of numbers after the fifth header record consisting of the relative elevations measured at different locations along the wheel path surveyed. Profile measurements will be made in the direction of traffic. There shall be as many records following the fifth header card, as there are longitudinal locations where elevation measurements have been collected.

For profilers capable of measuring two wheel paths in a travel lane at the same time with one pass, the profile data will consist of two columns of elevations. One set of measurements taken using the sensors on left side of the profiler, and the second set using the sensors on the right side. Profile measurements will be made in the direction of traffic. For these profilers, the spacing between wheel path sensors shall be set at 69 inches to be consistent with TxDOT practice. Thus, for each location where elevation measurements have been taken, there will be a record in the data file that will report the elevations for each wheel path tested, with a comma separating the two wheel path elevation readings at the same measurement location.

Optional Profile Data File

For profilers capable of inserting markers in the data during testing, a comment code will follow the last reported elevation for each measurement location. Comment codes will be a single numeric character from 0 to 9. There will be a comma separating this code from the last reported elevation at a given measurement location. The code will be zero if the elevation data is used in the determination of IRIs and pay adjustments. Non-zero values will cause the data to be thrown out. The non-zero value will be written to the data file through the entire length of the omitted area. The payment bonus/penalty will then be prorated for the interval outside the omitted data. A sample data file is shown in the 'Optional: Example Profile Data File' section of this test method.

Example Profile Data File

NOTE: Line numbers to the left are shown only for description purposes and are not part of each record.

11. HEAD3,06241999,17,21,SH0047S,0413 +00.200,R1
12. CMET3,Profiler_Model,,,,,123456ABCDEF,05211999
13. Manufacturer,mil,LR,5.4882,i
14. COMMENT
15. COMMENT
16. -797,-869
17. -796,-834

- 18. -781,-824
- 19. -752,-821
- 20. -746,-824
- 21. -752,-811
- 22. -738,-790
- 23. -702,-756
- 24. -696,-738

Optional: Example Profile Data File

NOTE: Line numbers to the left are shown only for description purposes and are not part of each record.

- 4. HEAD3,06241999,17,21,SH0047S,0413 +00.200,R1
- 5. CMET3,Profiler_Model,,,,,123456ABCDEF,05211999
- 6. Manufacturer,mil,LR,5.4882,i
- 7. COMMENT
- 8. COMMENT
- 9. -797,-869,0
- 10. -796,-834,0
- 11. -781,-824,0
- 12. -752,-821,0
- 13. -746,-824,9
- 14. -752,-811,9
- 15. -738,-790,9
- 16. -702,-756,9
- 17. -696,-738,0

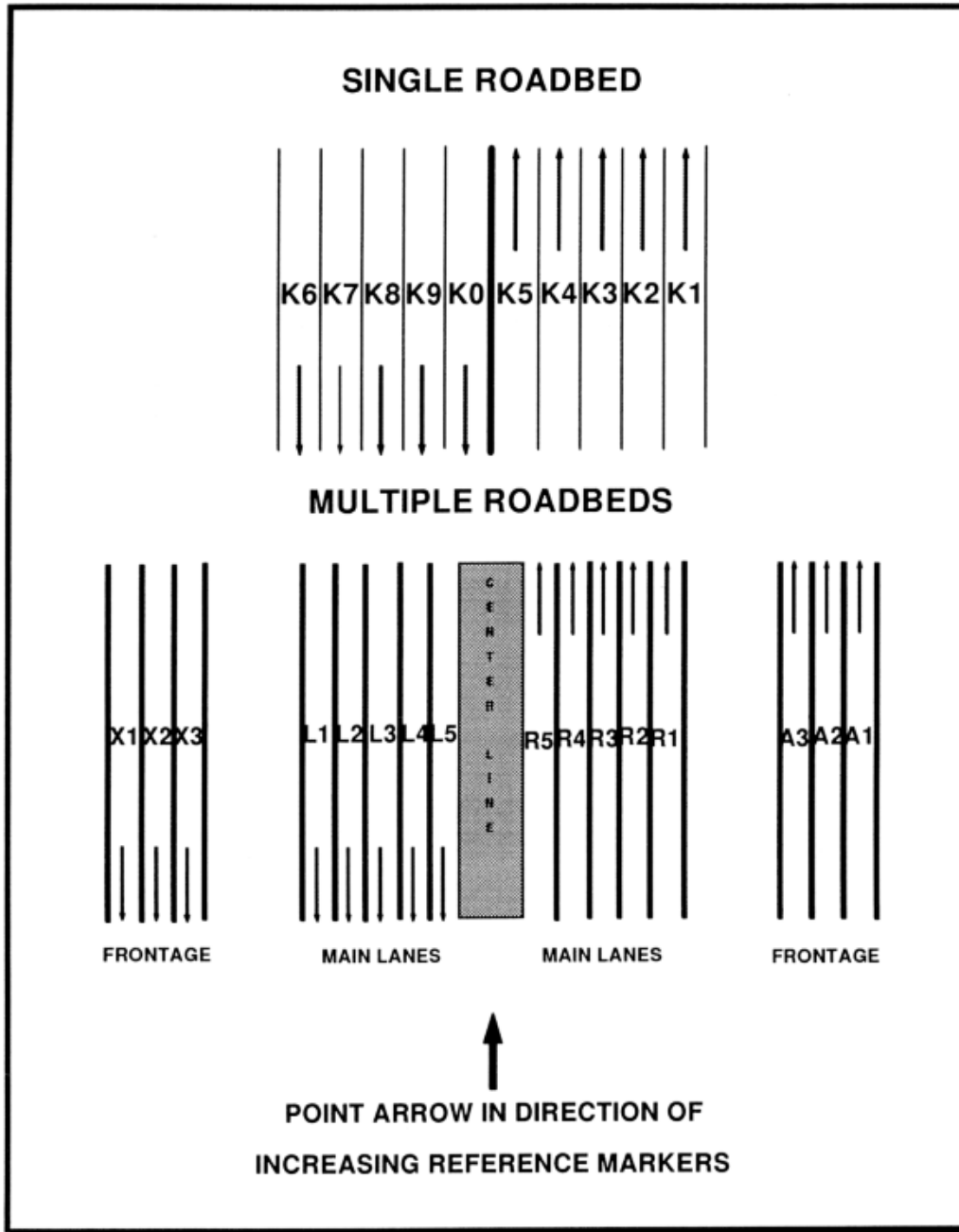


Figure Error! No text of specified style in document.-1. PMIS Lane Designations.

Detecting Localized Roughness

Areas of localized roughness shall be identified using TxDOT software with the same measured profiles required for QA tests.

The TxDOT software will average each elevation point from the two longitudinal profiles from a travel lane to produce a single averaged wheel path. The averaged wheel path

profiles will then be placed through a 25-foot moving average filter. The difference between the averaged wheel path and the 25-foot moving average filter for every profile point is determined. Deviations greater than 0.15 inches are considered a detected area of localized roughness. Positive deviations are considered “bumps” and negative deviations are considered “dips.” The following reference is provided illustrating the methodology: “Application of Profile Data to Detect Localized Roughness” TRB#02-4050, by Emmanuel Fernando and Carl Bertrand, Transportation Research Board, 81st Annual Meeting, January 13 – 17, 2002, National Academy of Sciences, Washington, D.C.

Inertial Profiler Certification

This section provides minimum requirements for inertial profilers to be used for quality assurance (QA) of surface smoothness on TxDOT paving projects where the profile-based smoothness specification is enforced. The Texas Transportation Institute (TTI) shall administer the certification for TxDOT.

The certification procedure covers test equipment that measures longitudinal surface profile based on an inertial reference system that is mounted on an inertial transport vehicle such as that shown in 'Illustration of a lightweight inertial profiler developed by TxDOT.' The minimum requirements stipulated herein are intended to address the need for accurate, precise, uniform and comparable profile measurements during construction.

Minimum Requirements

Operating Parameters

The inertial profiler must be capable of providing relative elevation measurements that meet the following requirements:

- ◆ Reporting Interval - the interval at which relative profile elevations are reported must be less than or equal to six inches.
- ◆ Cutoff Wavelength - the algorithm for filtering the profile data must use a cutoff wavelength of 200 feet to be consistent with current TxDOT practice.

The profiler must also be able to calculate and report the IRI (in inches/mile) from the corresponding measured profile and permit the operator to:

- ◆ automatically trigger the start of data collection at the designated location;
- ◆ provide the measured profiles in electronic text files following the format prescribed by TxDOT in the ‘Test Data Description and Format’ section of this document. The data may be presented in the optional data format as well;
- ◆ evaluate profiler accuracy and repeatability as described in this document; and
- ◆ verify the height and distance measurements as described herein.



Figure **Error! No text of specified style in document.**-2. Illustration of a lightweight inertial profiler developed by TxDOT.

Equipment Certification

On an annual basis, the inertial profiler must undergo certification tests to establish that it complies with the minimum requirements for accuracy and repeatability set forth in this test method. A profiler must also undergo certification testing after undergoing major component repairs or replacements as identified in this test method.

To monitor compliance with this requirement, an item will be included in the contract documents for a given project attesting that the contractor knows and understands the requirements for profiler certification as stipulated in this test method, and that each profiler to be used on the project is current in its certification. Equipment certification involves using the inertial profiler to collect profile data on test sections designated by TxDOT for this purpose. Prior to equipment certification, it is recommended that the owner of the profiler verify the horizontal and vertical calibration of his or her equipment following the procedures given under ‘Horizontal Verification of Calibration’ and ‘Vertical Verification of Calibration.’ This verification shall be carried out at the owner’s facility to permit any necessary re-calibrations to be made prior to the scheduled date of certification testing.

◆ Profile Tests

- Test Sections - Certification tests will be conducted on test sections designated as smooth and medium-smooth at a facility approved by TxDOT. Each section will be 0.1-mile in length. Ten repeat runs of the inertial profiler shall be made on the designated wheel path of each test section in the prescribed direction of measurement. For the purpose of evaluating the profiles from the test equipment, the profile of the test wheel path on each section shall be measured using static level methods.

- Test Data - Refer to 'Test Data Description and Format' and 'Example Profile Data File' for descriptions and formats of the data file. Additional information specific to certification testing and dual-path inertial profilers is found in this section.
During the certification tests, the same wheel path(s) is measured for all runs on a given test section. There will be twice as much data collected and analyzed when dual-path inertial profilers are tested. To facilitate the analysis of the data, the files from the tests described herein shall be named according to the following convention:
 - The first four characters of the file name are reserved for identifying the profiler tested. This identification will be established by the testing agency and given to the operator of the profiler on or before the day of testing.
 - The fifth character shall be S for runs made on the smooth section or M for runs on the medium-smooth section.
 - The sixth and seventh characters shall designate the run number (01 to 10).
 - The eighth character shall designate the wheel path tested. For dual-path profilers, the letter B shall be used to indicate that both wheel paths were profiled in the same run. For single-path profilers, the designation for the test wheel path will be given by the testing agency to the operator of the profiler by the day of testing.

The extension PRO shall be used for the data files to be provided by the operator of the profiler.

Test data will be analyzed as described in the following to establish the repeatability and accuracy of the test equipment.

- Equipment Repeatability - To evaluate repeatability, the standard deviation of the ten repeat measurements at each reporting interval will be computed for each wheel path surveyed. These standard deviations will be calculated for all reporting intervals.
For each wheel path, the average of the standard deviations at the different reporting intervals will be determined. Thus, for single-path inertial profilers, two averages will be determined, one for the smooth, and the other for the medium-smooth section. For dual-path profilers, four average standard deviations will be determined, two for each section. To pass the repeatability test, each average standard deviation must not exceed 35 mils.
- Equipment Accuracy - The benchmark or reference profiles on the test section shall be established using static methods such as the rod and level, Dipstick and/or other suitable devices that provide unfiltered profiles. As a minimum, reference elevations shall be collected at intervals no greater than six inches.
Devices that measure and integrate differential elevations, such as the Dipstick and Walking Profiler, may be used to establish the benchmark profiles. However, the measurements from these devices must be checked with the rod and level at distances along the test wheel path that are multiples of the reporting interval for these devices.
For the Dipstick, the reporting interval is 12 inches, while for the Walking Profiler, it is 9.5 inches. Benchmark profiles obtained from the Walking Profiler shall be

checked against rod and level measurements at 95-foot intervals along the test wheel path.

Dipstick measurements shall be checked against the rod and level at 100-foot intervals. Reference profile measurements shall be made on the designated wheel path of each test section as well as on the lead-in to the section. The lead-in distance shall be at least 300 feet.

The reference profiles shall be filtered using the same filter type implemented with the profiler tested. For this purpose, the owner or manufacturer of the profiler shall provide an IBM-compatible computer program to accomplish this filtering. The testing agency shall use this program to filter the reference profiles for evaluating the accuracy of the measurements from the profiler. This program must be set up to use a 200-ft cutoff wavelength and read the reference profile from an ASCII or text file that has the format shown in the 'Example Profile Data File.' Additionally, the program must output the filtered reference profile in an ASCII or text file according to the format given in the 'Test Data Description and Format.' The executable copy of the filter program shall be kept by the testing agency.

The test profiles will be synchronized, as necessary, so that the interval between reported elevations is the same as the interval between points in the filtered reference profiles. To evaluate accuracy, the average profile from the ten repeat runs on a given wheel path is determined. This is done by computing the mean of the relative elevations from the ten repeat runs on a point-by-point basis, i.e., at each reporting interval. In the same manner, the average of the filtered reference profiles on the test wheel path is also determined. For the determination of the average filtered reference profile, at least three repeat measurements of the profile shall be used. Differences between the average test profile and the average filtered reference profile are then calculated, point-by-point. The average of these differences (μ_1), as well as the average of the absolute differences (μ_2) are computed to establish the accuracy of the inertial profiler. The average difference is a measure of the bias in the data from a given profiler. The closer this statistic is to zero, the better the indication that a given profiler does not tend to underestimate or overestimate the profile relative to the reference used. It may be positive or negative. On the other hand, the average of the absolute differences indicates the degree of agreement between the test and reference profiles. The smaller the magnitudes of the absolute differences between the test and reference profiles, the closer this statistic is to zero.

For single-path profilers, two sets of μ_1 and μ_2 are determined, one set for each test section. For dual-path profilers, four sets of these statistics are determined, two for each section. To pass the accuracy test, the average of the point-to-point differences, μ_1 , must be within ± 20 mils and the average of the absolute differences, μ_2 , must not be greater than 60 mils for all sets of statistics determined.

- Verification of Computed Ride Statistics - The test equipment must be capable of computing and reporting the IRI of each wheel path tested. The repeatability of these ride statistics shall be determined in the following manner:
 1. Ten IRI values are computed using the profiles from the ten repeat runs made on a given wheel path.

2. For each test wheel path, the standard deviation of the IRIs is computed. For single-path profilers, two standard deviations are determined, one for each section. For dual-path profilers, four standard deviations are computed, two per section.
3. To pass the repeatability test based on the computed ride statistics, each standard deviation of the IRIs determined in step (2) must not exceed 3.0 in/mile.

The average of the IRIs is also determined for each wheel path. To evaluate the accuracy of the IRIs from the test data, the average IRI is compared against the corresponding average determined from the unfiltered reference profiles. The absolute difference between the average IRIs from the profiler and the reference must not exceed 12 in/mile for each wheel path tested.

Test Results

The results of the certification tests shall be reported by the testing agency and shall include the following information:

- ◆ identification of the profiler tested
- ◆ operator of the profiler
- ◆ name of the individual from the testing agency who conducted the test
- ◆ date of test
- ◆ number of paths the profiler can measure in the same run
- ◆ filter type, name of the filter program and the applicable program version number used to evaluate the profiler accuracy
- ◆ overall determination from the test: Pass or Fail
- ◆ individual test results determined from the profile data, which shall include:
 - average standard deviation of repeat profile measurements;
 - statistics, μ_1 and μ_2 , for evaluating the accuracy of the profiles with respect to the reference;
 - standard deviation of the IRIs computed from the profiles;
 - the absolute difference between the average of the IRIs determined from the profiler test data on a given wheel path, and the average of the IRIs determined from the unfiltered reference profiles on the same wheel path.
 - The report will also label each test result with a Pass or Fail depending on whether the given test value meets or fails to meet the prescribed criterion. The profiler must pass all tests to be certified. A decal shall be placed on the profiler as evidence of certification by the certification agency. This decal shall show the expiration date (month and year) of the certification.

Operator Certification

Operators of inertial profilers used for QA testing of pavement ride quality must pass a proficiency test and be certified to operate an inertial profiler in Texas. The Texas Transportation Institute (TTI) shall administer the test for TxDOT. Applicants for certification will be tested on the following:

- ◆ Special Specification Items 5880 and 5440, Ride Quality for Pavement Surfaces
- ◆ Test Method Tex-1001-S
- ◆ verification of profiler calibration and collection of profile data.

Applicants for operator certification shall undergo both written and practical examinations. The written examination shall be conducted following a multiple-choice format with questions that cover the following items:

- ◆ Ride Specification
 - required documentation for equipment and operators under Surface Test Type B
 - applicable areas profiled under Surface Test Type B
 - quality assurance testing under Surface Test Type B.
- ◆ Tex-1001-S
 - inertial profiler components
 - verification of profiler calibration
 - profile measurements with inertial profilers
 - profile data format
 - inertial profiler certification.

Applicants for operator certification must get a score of 70 to 100 percent to pass the written portion of the proficiency test. Applicants passing the written examination shall then be permitted to take the practical portion of the test. The practical examination will require the applicant to have undergone independent training on the use of the specific inertial profiler that he or she will be operating in the field. Additionally, the applicant must bring the inertial profiler with him/her at the time of testing. The practical examination shall cover the following areas:

- ◆ verification of profiler calibration
- ◆ profile measurements.

The applicant shall demonstrate that he or she can perform the horizontal and vertical calibrations described under ‘Verifying Calibration’ in this test method. Additionally, the applicant shall be asked to take profile measurements along a given route established by the testing agency. The route shall be at least 2500 feet long, with designated 0.1-mile test sections and leave-out segments. The applicant shall profile the designated wheel paths of the test route in the specified direction following the procedures given in this test method. He/she shall provide the test data in electronic files following the requirements stipulated in ‘Measuring Pavement Profile for QA Purposes.’ For the practical examination, the

applicant's performance is simply evaluated as passing or failing. The applicant must pass both areas of the practical examination, in addition to getting a score of 70 percent or higher in the written examination to qualify as a certified inertial profiler operator in Texas.

Upon passing the proficiency test, the successful applicant will be given an identification card, which will verify that he or she is certified to operate an inertial profiler for QA testing on TxDOT paving projects. The card shall identify the specific type or brand of inertial profiler that he or she is certified to operate. This card will be valid for an initial period of 12 months from the date of issue unless earlier revoked by TxDOT because of misuse. Upon expiration, the operator must take another proficiency test to be re-certified.