Method of Test for

DETERMINING THE LONGITUDINAL PROFILE ROUGHNESS OF TRAVELED SURFACES USING AUTOMATED PROFILERS

DOTD Designation: TR 644

INTRODUCTION

This method describes the procedure to be used for measuring and reporting the longitudinal profile roughness of traveled surfaces using an inertial profiler (automated profiler). Inertial profilers are devices used to produce a filtered approximation of the "true" pavement profile using non-contact sensors to measure the relative displacement between the vehicle frame and road surface.

Surface data that is obtained by this method is reported as International Roughness Index (IRI). The IRI simulates a vehicle's response to the deviations. IRI values are calculated on a quarter-car mathematical model that simulates the suspension characteristics of a passenger car to the collected profile. This test procedure is the department's official standard for determining the IRI of pavement surfaces.

Only DOTD certified and approved profilers can be used on DOTD projects. Profilers are evaluated and certified annually by the Materials and Testing Section to ensure conformance with the apparatus requirements of this procedure. The precision and bias of IRI measurements using the profiler on test sections of known values are determined during the evaluation program. After 10 test runs, the standard deviation of the IRI results obtained from the profiler must not exceed 3 IRI for each sensor. The mean IRI value shall be within ±6 of the reference IRI as determined by the department's Australian Road Research Board (AARB) Walking Profiler. Approved profilers are identified with a certification decal indicating the certification expiration date, the certification number, and profiler system parameter settings. The profiler decal and certification must be present with the profiler at all times.

Recertification of profilers is required annually and whenever major component repairs, replacements, or modifications are made to the accelerometer and its associated hardware, sensors and its associated hardware, distance transducer, data acquisition system, or tire replacement. Minor repairs and adjustments can be performed without having the profilers recertified provided the profiler system meets the pre-operation test requirements shown in this procedure. Minor repairs and adjustments include re-soldering or replacing connectors, cleaning components, tire pressure adjustments, adjusting sensor spacing to align over wheelpaths, and setting software parameters as shown in this procedure. Recertification of profilers is also required when requested by the department. All project information, pre-operation test results, daily tire pressure checks, descriptions of all major repairs, component replacements, and other modifications must be recorded by the profiler operator for DOTD perusal. Records may be manual or electronic. DOTD may request to view these records at any time.

I. Scope

A. This method describes the procedure for measuring and reporting the longitudinal profile roughness of a pavement's surface using the inertial profiler. Also included in this procedure are standard pre-operation tests to verify the calibration of the profiler.

B. Ride quality as determined from this procedure is reported as the International Roughness Index (IRI).

II. Apparatus

A. Approved inertial profiler - a device that has been certified and approved by DOTD, configured to meet the requirements of ASTM E950 Class I or II. Certified profilers are designated with a decal indicating the certification expiration date, certification number, filter settings as verified or determined by the Materials and Testing Section. The profiler shall include at a minimum:

1. A vehicle large enough to accommodate all the required equipment without major structural modifications. The engine, steering mechanisms, and suspension components shall be adequate to allow smooth maintenance of speed and direction of travel.

B. Data Acquisition and Reporting System - mounted on the vehicle, to store and process sensor, accelerometer, and distance measurement data. This system must be capable of producing an electronic file recognized by the ProVal Software, such as .ard, .adf, .ldf, .rsp, .pro, and .erd format, along with an electronic and/or paper copy of daily results in conformance with the reporting requirements of this procedure. The system is to come equipped with an automatic triggering device that can immediately activate a start and stop point when a reflective tape or cone is passed. The data acquisition system shall include an "event" key button that will identify excluded areas which are not to be included in IRI calculations. The computer must contain a USB Port for a USB storage device. The printer shall be a high-speed thermal printer or laserjet. The computer system shall be equipped with a Microsoft Windows operating system. The software shall be capable of calculating IRI. The software shall also accommodate system set up and pre-operation tests in accordance with the requirements in this procedure. Also required are the following:

1. Non-contact Height Sensors - mounted on the vehicle with its measuring axis perpendicular to the traveled surface and in line with the sensitive axis of the accelerometer. The sensors shall be housed in a manner to protect the lasers or infrared sources from damage when not used.
2. Accelerometers - mounted on the vehicle with its sensitive axis perpendicular to the traveled surface.
3. Distance Transducer - capable of measuring travel distance of the vehicle within 0.1% of the actual distance traveled.

4. The collection interval shall be set to 1.0 inch.
5. The high pass filter must be set at 300 feet.

C. Metal Calibration Blocks - provided by the profiler manufacturer, for the validation of the non-contact sensors in accordance with the manufacturer's recommended procedure. The blocks shall consist of a base plate and gauge blocks having thicknesses of 0.25 in., 0.50 in. and 1.00 in or a set of blocks to perform an equivalent series of calibration tests. The acceptable thickness tolerance for each block is ±0.01 in.
D. Portable Air Pump and Tire Pressure Gauge
E. Measuring Tape/Measuring Wheel - minimum 100 ft measuring tape
F. Transport Vehicle - for transporting a lightweight inertial profiler and supporting equipment.
G. Certification Report - for inertial profiler issued by the DOTD Materials and Testing Section.
H. Marker - Paint, stakes, etc.
I. Suitable cleaning material - as recommended by the manufacturer for cleaning non-contact sensor and other essential equipment.
J. Alignment Bar (for lightweight profilers only) - approximately 3 ft in length mounted on the front of the profiler to maintain sensor alignment over the wheelpaths.

III. Terminology

A. International Roughness Index (IRI) - A number used to estimate the amount of roughness in a measured longitudinal profile. IRI is based on the response of a generic passenger vehicle to roughness of the road surface. It was developed as a reference measurement by The World Bank, and is based on a quarter car simulation as described in National Cooperative Highway Research Program (NCHRP) Report 228 and in the introduction of this procedure.
B. Excluded Areas - Areas that are not included in the calculations for surface roughness for the lot. Excluded areas are identified by the Project Engineer and may be measured separately for surface roughness. Refer to LA DOTD Specification 501, 502, 601, or 805 for specific guidelines.
C. Collection Interval - The travel distance between recorded elevation readings as collected by the inertial profiler used to measure roughness.
D. High Pass Filter (Long Wavelength) - the mathematical transformation which removes long wavelengths.
E. Non-contact Sensors - Laser or infrared sensors that measure the distance between the accelerometer on the profiler and the traveled surface. Non-contact sensors are mounted on the vehicle with its measuring axis perpendicular to the traveled surface.
F. Wheelpath - For the purpose of this procedure, the wheel path is defined as 3±1/2 ft from the centerline of the lane to be tested.

IV. Test Section

Note 1: *Refer to LA DOTD Specification 501, 502, 601, or 805 for specific guidelines and tolerances.*

A. Identify and mark the beginning and ending points of the lane to be tested. The direction of travel of the inertial profiler shall be consistent with the travel direction of the lane, except in extenuating circumstances such as areas which would not otherwise have sufficient lead-in.
B. Identify and mark excluded areas that are within the test section.
C. Assure test path is free of standing water and loose debris.

V. Preparation

A. Remove the profiler from the transport trailer or attach profiler to vehicle and place on a flat and level surface.
B. Turn on the laptop computer and the processing computer.

Note 2: *On some units, the ignition key must be turned on in order for the laptop and processing computers to operate.*

C. Check and adjust the tire pressure for each tire on the profiler in accordance with the manufacturer's recommendations. (Lightweight profilers' tire pressure shall be checked on cold tires.) Drive the unit for 15 to 20 minutes to warm the tires.
D. Securely fasten the alignment bar and non-contact sensors so that the sensors will be aligned over the wheelpaths of the test section.
E. Slide or remove the protective cover that is located beneath each sensor to expose the lasers and, if necessary, clean each laser with manufacturer's recommended cleanser to remove foreign matter.

Note 3: *The reflection of the laser on the pavement surface will be faintly visible when the protective cover is removed. Never look directly into the laser openings since lasers are harmful to the eyes.*

F. Perform the Set Up procedures in accordance with the manufacturer's setup instructions and DOTD requirements. Reference the certification report for settings.
G. Perform the Pre-Operation tests in accordance with Appendix A before taking surface roughness measurements each day and whenever the operator or inspector suspects changes in system performance.

VI. Procedure

A. Input the following into the computer: the beginning station number, operator's name, project number, direction of travel, lot number, sublot number, and type of pavement for the test section according to the manufacturer's instructions. Include roadway side (left or right) and directions (NSEW) in the remarks.

B. A lead-in and lead-out of a minimum of 300 feet is required at the beginning and end of all test sections. The lead-in begins a minimum of 300 before the test section starting point. The lead-out begins at the end of the test section and continues for a minimum of 300 feet after the test section. Accelerate the profiler so that it is collecting accurate profile data within the range specified on the certification report.

C. When the beginning point of the test section is reached, activate the data acquisition system using the profiler's photo cell according to the manufacturer's instructions.

D. Maintain a constant speed throughout the test section while keeping the non-contact sensors located over the wheelpaths.

E. Flag excluded areas with the event key.

F. At the end of the test section, end the data collection using the profiler's photo cell, complete the minimum 300 feet lead-out, and save the data files.

G. Copy the data files (.erd, .pro and either .ard, .adf, .ldf, or .rsp and .tbl or .iri depending on model of profiler) for each wheelpath to the USB Storage Device. Record project information manually or electronically, including data files names.

H. Print a computer generated report containing the information in Step VIII.A.

Note 4: *For Quality Assurance, the measurements shall be performed by the contractor in the presence of a Department qualified representative, by the Materials and Testing Section, or by a private company approved by the Department. The Department representative will ride along with the contractor or private company during data collection.*

VII. Data Analysis & Calculations

Refer to LA DOTD Specification 501, 502, 601, or 805 for specific guidelines and tolerances.

Calculate the IRI to the nearest 0.1 inch per mile.

VIII. Report

A. IRI Report - A computer generated report containing the following information shall be given to the inspector for the project files upon completion of the test:
Project Number
Route / Highway Number
Lane Location and Direction
Parish
Contractor's Company Name
Profiler Operator's Name
Profiler Serial Number
DOTD Inspector's Name
Test Section / Lot Number
Electronic File Name(s)
Must include corresponding location on project
Job Category
Test Date
Profile Data
Stations Profiled
Bump / Dip Locations
IRI (reported to the nearest 0.1 inch per mile) as required by specifications

Appendix A

Pre Operation Tests:

1. **VERTICAL MEASUREMENT (BLOCK) TEST:** The vertical measurement (block) test verifies that each non-contact sensor (ODS1 and ODS2) is working properly by taking thickness measurements of the base plate and metal calibration blocks. The average difference for each block must not exceed 0.01 inch. The operator should not be inside the vehicle during testing.

   Movement of the profiler or calibration blocks can cause failing results during the vertical test. The accelerometer compensates for variations in horizontal and vertical movement of the profiler during the performance of the surface roughness test. Since the profiler is stationary during the pre-operative vertical test, failing results may be caused by the wind. Also, damaged calibration blocks may cause failing results. Therefore, if the values shown for Average Difference are greater than 0.01 inch between block sizes, relocate the device where wind is not a factor or change calibration blocks and repeat the vertical test. However, radical changes in the Average Differences indicate equipment malfunction and the manufacturer should be notified.

2. **VERTICAL BOUNCE TEST:** The bounce test allows the operator to verify the interaction of the optical displacement sensor(s) and accelerometer(s) such that vehicle bounce is cancelled out during actual surface roughness testing. This test simulates the accumulation of data over a 500-ft test section even though the vehicle remains stationary during the test.

   Extreme care should be taken to ensure that the bounce test for the lightweight profiler is performed while standing in the center of the profiler between the driver and passenger seats and that only vertical movement occurs. Any side-to-side movement will cause failing results. The bounce test for the high speed profiler is performed while standing at the center of the bumper in which the unit is attached ensuring only vertical movement occurs. If, after several attempts, passing results cannot be obtained for either sensor, the manufacturer should be notified.

3. **HORIZONTAL CALIBRATION:** This procedure will calibrate the distance transducer on the profiler over a pre-determined distance along a straight section of roadway. Daily calibration compensates for changes in tire pressure and tire wear on the profiler. It is recommended for all lightweight profilers to use a minimum of 528 ft and all high speed profilers to use a minimum of 1,000ft. The calibration distance may be increased as needed for longer projects. The longer calibration lengths are more accurate over distance.

4. **HORIZONTAL TEST:** This procedure will allow the operator to test the accuracy of the horizontal calibration. The same location used during the horizontal calibration should be measured using the odometer on the profiler.

   An error larger than 0.1% of the actual distance shall not be accepted. If the horizontal test indicates the traveled distance exceeds the 0.1% limits, check the distance measured for the horizontal calibration. If necessary, repeat the Horizontal Calibration and Horizontal Test until the error is less than or equal to 0.1% of the actual distance traveled. If after three unsuccessful attempts the error still exceeds 0.1%, notify the manufacturer and discontinue use of the profiler.