Commonwealth of Pennsylvania
Department of Transportation

PA Test Method No. 428
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14 Pages

ASSET MANAGEMENT DIVISION

Method of Test for

MEASURING PAVEMENT PROFILE USING A LIGHT WEIGHT PROFILER

1. SCOPE

1.1. This test method covers the measurement of pavement profile and roughness using a Light Weight Profiler by driving the profiler longitudinally over the pavement.

1.2. This test method covers the determination of the pavement ride quality from the longitudinal profile, in the form of the International Roughness Index (IRI), for acceptance and payment.

1.3. This test method covers the calibration verification procedures and it outlines the procedures for collecting Light Weight Profiler data on paving projects.

1.4. This test method covers the submission requirements for projects with a ride quality specification.

2. REFERENCED DOCUMENTS

2.1. NCHRP Report 228 Calibration of Response-Type Road Roughness Measuring Systems

2.2. ASTM Standards

- E950/E950M Standard Test Method for Measuring the Longitudinal Profile of Traveled Surfaces with an Accelerometer Established Inertial Profiling Reference
- E1926 Standard Practice for Computing International Roughness Index of Roads from Longitudinal Profile Measurements
- E2560 Standard Specification for Data Format for Pavement Profile

2.3. AASHTO Standards

- R 56 Standard Practice for Certification of Inertial Profiling Systems
- R 57 Standard Practice for Operating Inertial Profiling Systems

2.4. PennDOT Publications and Forms

- Publication 408, Specifications

- Publication 589, Light Weight Profiling System Calibration Verification and Operator Certification Program Manual
- Publication 2, Project Office Manual, Section B.6.23, Verification Process for Ride Quality of Newly Constructed Pavements
- Form M-7, Contractor IRI Data Collection Form

3. TERMINOLOGY - DESCRIPTION OF TERMS SPECIFIC TO THIS PTM

3.1. International Roughness Index (IRI) - A scale for roughness based on the response of a generic motor vehicle to roughness of the road surface. IRI was developed as a reference measure by The World Bank, and is based on a quarter-car simulation as described in NCHRP Report 228. IRI is determined by obtaining a suitably accurate measurement of the profile of the road, processing it through an algorithm that simulates the way a reference vehicle would respond to the roughness inputs, and accumulating the suspension travel.

3.2. Excluded Area - An area that is not included in the measurement, used to determine lot payment.

3.3. Light Weight Profiler System (LWP) - An inertial profiler that is relatively lightweight (golf cart, ATV, etc.) compared with high-speed profilers. It is often operated much more slowly than prevailing traffic speed.

3.4. Raw (Unfiltered) Binary Data – Inertial profiler output files that have not been filtered and are saved in binary, encrypted form. Profiler manufacturers use various file extensions to save the profile, speed and elevation data which are required for the data to be reprocessed as the user needs. Refer to your profiler's manufacturer for questions regarding your equipment's raw binary output files.

3.4.1. Engineering Research Division (ERD) – A file format developed within the Engineering Research Division of the University of Michigan Transportation Research Institute (UMTRI). ERD is the standard file format used by ProVAL, an engineering software application that allows users to view and analyze longitudinal pavement profiles.

3.4.2. Pavement Profile Standard File Format (PPF) – A binary based file format created for ProVAL, an engineering software application that allows users to view and analyze longitudinal pavement profiles. The ASTM International profile data file specification, E2560, is based on this format.

4. APPARATUS

4.1. The Light Weight Profiling System must be an all-terrain or golf-cart type vehicle equipped with various hardware and software that together allow the measurement and recording of the longitudinal profile of a traveled wheel track and the reference distance traveled along the traveled wheel track.

4.2. The equipment and software will produce an IRI in English units (inches/mile) for 0.10 mile intervals conforming to ASTM E1926 and meet the requirements of Appendix A, Generic Specification for Light Weight Profiling System.

4.3. Must be certified for use on PennDOT projects described in Section 6.

5. REPAIR AND ADJUSTMENT OF LIGHT WEIGHT PROFILER

5.1. Major component repairs or replacement that would require recertification of the inertial profiler include, but are not limited to, the following:

5.1.1. the accelerometer and its associated hardware,

5.1.2. the non-contact height sensor and its associated hardware,

5.1.3. the distance measuring instrument, or

5.1.4. any printed circuit board necessary for the collection and processing of raw sensor data of the LWP and IRI.

6. ACCEPTANCE

6.1. This section provides minimum certification requirements for LWP devices and operators.

6.1.1. Prior to testing, the LWP device will be checked to verify that it has been calibrated and is operating properly.

6.1.1.1. Verification/certification will be done in accordance with Publication 589.

6.1.1.2. Accepted profilers are designated with a decal that is valid until June 30 of the following calendar year provided no changes are made to the equipment or software. The decal must adhere to the outside of the LWP in clear view.

6.1.1.3. Additional reverification/recertification of profilers or operators may be required, due to repairs, replacements, and/or upgrades to the profiler's hardware or software, or questionable results and/or practices on a construction project.

6.1.2. The LWP operator must be certified. Certified operators will receive individual certification cards that are valid for up to three calendar years.

6.1.3. The operator of a certified LWP must use the same software version and settings on PennDOT projects that were used during the profiler certification. A copy of these settings may be obtained by contacting the Roadway Inventory and Testing Unit or by viewing the Roadway Inventory and Testing Unit's website at http://www.penndot.gov/ProjectAndPrograms/ResearchandTesting/RoadwayManagementandTesting/Pages/Light-Weight-Profiler-Certifications.aspx#.VmsrSqMo670.

6.1.4. Changes to the software version may result in the need for reverification or recertification of the profiler.

7. PROJECT SITE VERIFICATION

7.1. The Department shall certify all light weight profilers and operators prior to testing.

7.2. The Project Engineer (or designee) will approve the operator and equipment for project level testing by verifying the equipment and software information on the PennDOT issued decal and by verifying the operator has a current PennDOT issued certification card. The operator and equipment information shall be documented by the Project Engineer (or designee) on the Form M-7. A list of approved contractor operators and approved equipment is posted on the Bureau of Maintenance and Operations, Asset Management Division, Pavement Testing and Asset Management Section, Roadway Inventory and Testing Unit's webpage.

7.3. The following daily verification procedure is required for all testing. Although the specific steps to complete the verifications will vary in accordance with the manufacturer's recommendations, the basic procedures will not change. The results of the verification checks shall be documented in a log. The Project Engineer (or designee) shall verify the profiler meets the following requirements:

7.3.1. Longitudinal Verification (Distance)

7.3.1.1. The longitudinal calibration will be a straight roadway test section at least 528 feet in length. This distance shall be measured accurately within +/-0.1 % using a steel measurement tape or electronic measuring device.

7.3.1.2. Verify the tire air pressure on the wheels of the apparatus daily and maintain per the vehicle manufacturer's recommendations.

7.3.1.3. Warm up the LWP's tires and electronic systems in accordance with the manufacturer's recommendations.

7.3.1.4. If the LWP's distance measuring subsystem measures the length of the test section to within 0.1% of its actual length, no additional verification is necessary.

7.3.1.5. If the LWP's distance measuring subsystem fails to measure the length of the test section to within 0.1% of its actual length, the calibration shall be adjusted according to the manufacturer's guidelines and the longitudinal verification repeated.

7.3.1.6. No more than one single certified operator is to occupy the profiler during verification/calibration.

7.3.1.7. If the LWP fails to meet these requirements, the LWP will be deemed to be not certified and prohibited from use on PennDOT projects until it is recertified.

7.3.1.8. A printed copy of the distance calibration must be submitted to the PennDOT representative each day prior to taking any measurements.

7.3.2. Laser Height Verification (Block Test)

7.3.2.1. Laser height verification must be performed in accordance with AASHTO R 57-14 or the manufacturer's recommended procedures each day the LWP device is in use.

7.3.2.2. The block sensor tests are run after the profiler has reached operational stability as defined and specified by the manufacturer. This test should be performed on a flat level area. Its purpose is to check the height measurements, in inches, from the height sensor(s) of the LWP using blocks of known heights. During the test, do not lean on the LWP or cause it to move in any way. At a minimum, two base plate and three varying measurement plate (typically 0.25, 0.5 and 1 inch) readings will be needed. The absolute difference should be less than or equal to 0.01 inch for each gauge block.

7.3.2.2.1. Center the base plate under the height sensor of the LWP and allow the system to take height measurements.

7.3.2.2.2. Center a 0.25 inch block underneath the height sensor on top of the base plate and record the height measurement.

7.3.2.2.3. Replace the 0.25 inch block from the base plate with a 0.50 inch block and record the height measurement.

7.3.2.2.4. Replace the 0.50 inch block from the base plate with a 1.0 inch block and record the height measurement.

7.3.2.2.5. Remove the 1.0 inch block leaving only the base plate and record the height measurement. The profiler's height measurement subsystem returns to zero.

7.3.2.2.6. If the tests fail to meet these requirements, the LWP will be deemed to be not certified and prohibited from use on PennDOT projects until it is recertified.

7.3.2.2.7. A printed copy of the laser height verification results must be submitted to the PennDOT representative each day prior to taking any measurements.

7.3.3. Vertical Verification (Bounce Test)

7.3.3.1. A bounce test in accordance with AASHTO R 57-14 or manufacturer's equivalent must be performed each day the LWP device is in use, prior to taking any measurements.

7.3.3.2. With the base plates in position simultaneously under both wheel path sensors, place the LWP in an operating mode that simulates longitudinal movement and initiate profile data collection. Allow the profiler to collect a minimum of 828 feet (includes a 300 foot lead-in) of static profile with the LWP as motionless as possible.

7.3.3.3. Sensor(s) should be moved vertically for a total displacement of approximately 1 to 2 inches keeping the sensors as close to perpendicular to the surface as possible during this movement. The bouncing must continue until a minimum of 528 feet of simulated distance has been traveled.

7.3.3.4. After a minimum of 528 feet of bounce profile is collected, allow the profiler to collect an additional minimum of 828 feet (includes a 300 foot lead-out) of static profile with the LWP as motionless as possible.

7.3.3.5. When reviewing the analysis results, the first and last (static) 528 foot segments shall not exceed 3 inches per mile, while the IRI for the middle (bouncing) segment shall not exceed 8 inches per mile for the bounce test. If the computed IRI values exceed 3 inches per mile for the static test and/or exceed 8 inches per mile for the bounce test, then the manufacturer's recommendations for performing sensor operational checks shall be followed. The static bounce test shall be repeated.

7.3.3.6. If the tests fail to meet these requirements, the LWP will be deemed to be not certified and prohibited from use on PennDOT projects until it is recertified.

7.3.3.7. A printed copy of the bounce test results must be submitted to the PennDOT representative each day prior to taking any measurements.

7.3.4. Accelerometer Verification

7.3.4.1. Accelerometer verification must be performed in accordance with the manufacturer's recommended procedures each day the LWP device is in use, prior to taking any measurements. The tolerance for the accelerometer verification must meet the manufacturer's requirements.

7.4. The operator will check that all sensor positions are displaying correctly, and verify that sensor collection rates are properly set. All such constants or factors must be automatically set and stored during calibration/verification procedures.

7.5. A calibration verification log, in accordance with AASHTO R 56, is to be kept with the inertial profiler to provide a verification of calibration history. The results of the routine bounce tests, block checks, accelerometer and distance verification runs shall also be included in this log. If the log is electronic, a backup copy shall be kept in a secure location.

8. PROCEDURE

8.1. Startup and initialization.

8.1.1. Clean the roadway path of all debris and other loose material before measuring.

8.1.2. Perform all necessary start up procedures.

8.1.3. Verify that distance measurement, sensors, and accelerometers are properly calibrated. Perform all necessary calibration procedures, as specified in Section 7, and as per equipment manufacturer procedures. Save all values.

8.1.4. Check that all sensor positions are displaying correctly, and verify that sensor collection rates are properly set.

8.1.5. Enter the location identification information (all data collected must have this information printed on all output files), and define the direction of traffic for the pavement to be tested.

8.1.6. Collect measurements in the direction of traffic. When using a LWP that collects a single wheel path per pass, take care to ensure that the measurements from each wheel path in a travel lane start and stop at the same longitudinal locations.

8.2. Sampling

8.2.1. Pavement profiles must be taken in the wheel paths of each lane. The first profile must be approximately 3 feet from and parallel to the outside edge of pavement, and the second profile must be approximately 5.75 feet from the first profile, or as directed by the Project Engineer.

8.2.2. Measure profiles to the limits of the pavement areas, as specified. As per Publication 408, sampling areas must be designated as lots, and excluded areas must be defined and measured separately (measure profiles of the excluded areas to their limits).

8.2.3. Only a single certified operator is to occupy the profiler during sampling. The weight of additional passengers, including Department personnel, may adversely affect results and is not permissible.

8.3. Data collection

8.3.1. Position the LWP to a point where the testing speed can be reached before testing begins. A 100 foot lead-in section of roadway is required to eliminate all error through filtering in the program that processes the data. This lead-in section should be located immediately before the section of pavement being tested. When this is not possible, then crop the beginning of the run until the LWP has reached testing speed and the systems have had a chance to stabilize, or add a minimum of 100 foot lead-in and/or lead-out through the report program to account for speed adjustments and system stabilization.

8.3.2. Verify that all software and hardware is ready to collect data. Start the data collection system.

8.3.3. The LWP shall remain stationary for approximately 1 minute for the system filters to stabilize.

8.3.4. Start the LWP moving and initiate testing when the LWP reaches testing speed.

8.3.5. If targeting is used, allow the target to reset the system at test start and finish.

8.3.6. Continue testing at a consistent speed until the test end point is passed. A lead-out may be used in accordance with the profiler manufacturer's operating requirements.

8.3.7. Terminate the test after the test end point is passed, or allow targeting to terminate the test.

8.3.8. End data collection and save the file. It is recommended to save all data, and then delete unwanted data later, rather than abort the file save mode.

8.3.9. If applicable, mark where the total file may be broken into smaller files for analysis.

8.3.10. Upon completion of a sampling path, make ending notations and review the test for reasonableness. Repeat the procedure, driving the LWP in the same direction for successive sampling paths for a given section of pavement. Test each sampling path only once. Additional profiles may be taken to define the limits of an out-of-tolerance surface variation.

8.3.11. Measure IRI for excluded areas separately.

9. WEATHER LIMITATIONS

9.1. Collect data only when the temperature and weather conditions are within the operating range recommended by the manufacturer of the light weight profiler.

9.2. Data collection is not permitted during precipitation.

9.3. Data collection is not permitted when standing water is present on the pavement.

10. SUBMITTALS

10.1. All test results shall be reported in English units (inches/mile).

10.2. Test values shall be reported to one digit to the right of the decimal in accordance with conventional rounding procedures.

10.3. Provide a summary printout of the IRI value calculated for each pass as generated by the equipment performing the test, within 24 hours of the conclusion of each test. IRI shall be calculated using a quarter-car simulation as outlined in NCHRP Report 228.

10.4. As a minimum, the following information must be printed from the inertial profiler for the interpreted output:

(1) Date and time of day
(2) Operator and equipment identification
(3) Weather conditions: temperature, cloud cover, and wind
(4) Surface description: type of pavement and condition
(5) Location and description of section: Job ID, lot, lane, wheel path, beginning and ending stationing, and direction measured
(6) Lot length
(7) Software version: both the LWP and the reporting software
(8) Data filter settings
(9) High-pass filter setting = 100 feet
(10) Lot IRI value: the average of the IRI values for the two wheel paths for each lot will be the IRI for the lot
(11) IRI values for excluded areas

10.5. Supply the necessary raw (unfiltered) binary data files, PennDOT Form M-7, and a copy of the operator's certification card for all projects. Provide a USB flash drive or CD that contains the raw (unfiltered) binary data for each wheel path, so that PennDOT may perform verification analysis. Each pass shall be clearly labeled to include county, state route, project number, lot number, and wheel path. The data file must be in ERD or PPF format.

End of PTM 428

APPENDIX A

GENERIC SPECIFICATION FOR LIGHT WEIGHT PROFILING SYSTEM

The purpose of this specification is to define the requirements for a Light Weight Profiling (LWP) System that can be used to collect roadway surface data for determining the roughness and profile of roads. The following items are required:

1. The computer based system, with its profile sensing system described must be capable of the following:

(1) interfacing with the operator
(2) controlling the tests
(3) measuring the necessary resultant test signal data
(4) recording the resultant test data on USB flash memory drive, Compact Disc (CD) or Digital Versatile Disc (DVD)
(5) calculating and storing profile, roughness, and distance values
(6) displaying the stored data
(7) printing the stored data upon operator request

2. The LWP operational system must be an all-terrain or golf-cart type vehicle equipped with various hardware and software that together allows the measurement and recording of the longitudinal profile of a traveled wheel track and the reference distance traveled along the traveled wheel track. The longitudinal profile must be measured using a concept where three transducers are used. These transducers include:

    (1) non-contact height measurement (sensor) subsystems, capable of measuring the height from the mounted sensor face to the surface of the pavement under test.
    (2) an inertial reference (accelerometer) subsystem, capable of measuring the movement of the LWP vehicle as it traverses the pavement under test.
    (3) a distance measuring subsystem which provides a reference measurement of the vehicle as it traverses the pavement, verified accurate to within 1 foot per 0.20 mile of actual distance traveled.

3. The data must be saved and recorded so that road profiles obtained with this system must be independent of the measuring speed and the type of vehicle used. The LWP must:

    (1) include hardware and software capable of producing and storing inertial profiles by combining the data from the inertial referencing subsystem, the distance subsystem, and the height measurement subsystem.
    (2) be capable of measuring and storing profile elevations at 1 inch intervals or less and outputting in ERD or PPF format.
    (3) have the capability of summarizing the profile elevation data into summary roughness statistics over a section length equal to 0.1 mile (the summary roughness statistic is the International Roughness Index (IRI) for each longitudinal path profiled). In addition, profile plots must be capable of being displayed and printed during post processing.
    (4) have design to allow field calibration and verification of calibration for the distance measurement (horizontal) subsystem and the height measurement (vertical) subsystem as required by agency standards.

4. The roughness value must be calculated using the standardized International Roughness Index (IRI). In addition to the normal IRI unit value the system must also provide an "inches/mile" statistic. The IRI was developed as a reference measure by The World Bank,

and is based on a quarter-car simulation as described in NCHRP Report 228. This value must conform to the requirements of ASTM E950/E950M. IRI measures obtained from this system must match those obtained from other valid profilometers, and also IRI measures obtained using agency approved ground truth devices. A plot of roughness using any base length for averaging must also be reproducible. The above roughness results must be displayable on the system screen, printed on a printer or written into an electronic file format for processing.

5. The profile system hardware and software for collecting and processing the data obtained in real time in conjunction with the post processing software must have as a minimum the following capabilities:

    (1) profile computation
    (2) IRI computation
    (3) high-pass filtering
    (4) low-pass filtering (smoothing)
    (5) height sensor error checking

6. The system must be capable of calculating, displaying, and storing the average roughness value obtained from the stored data. Additionally, the system must be capable of putting the accumulated roughness test results through mathematical equations and printing results when enabled by the operator. These options must be done in real time or in post processing. The system must be capable of performing all required post processing operations.

7. The test software must activate the testing using the timing and control parameters stored by the test control setup software.

    (1) The operational system through the Distance/Data Acquisition Subsystem (DAS) must provide all interfaces to collect data to derive distance, speed, and profile from the transducers mounted on the vehicle; activate the tests; derive distance and location information from the transmission mounted distance transducer; process operator inputs from the keyboard signaling that the test vehicle has encountered a significant feature; and pass information on about the feature and its location to the processing unit for display and logging.
    (2) The software must monitor the signals to verify that the testing is being performed properly and indicate detectable errors.
    (3) The test software must receive, display, and store raw data received from the vehicle mounted transducers at corresponding distances and test speeds.

8. An optical encoder must be mounted on the vehicle to produce a pulse for units of distance traveled by the vehicle on the roadway. The DAS must accept these pulses and, in combination with the DAS software, must determine the distance traveled and vehicle speed.

9. The operational system software must allow the operator to perform a distance sensor calibration and use the calculated Distance Calibration Factor (DCF) to perform the operational distance measurements. The calibration software must also allow the operator to save the calculated DCF. The operator must only enter the distance traveled in feet, meters, kilometers, or miles and not make any calculations to determine the DCF. Five feet per mile (or 1 foot per 0.20 mile), accuracy is required.

    (1) The calibration software must also allow the operator to perform a profile system calibration. The values determined in calibration must be stored and recorded as above for use in the calculation.

10. The reference height of the vehicle above the pavement must be obtained through a laser or infrared module as required. The sensor must be totally enclosed in a case that may be sealed during bad weather or when not in use. The sensor must be formed in a manner so that it may be mounted on a vehicle approximately 1 foot above the pavement surface. The laser or infrared module shall be equivalent to a Selcom sensor, which has a resolution of 0.001 inch. The sensor must provide continuous coverage of the roadway. The sensor module must send an infrared beam to the pavement and sample the height value at a rate of 16,000 times per second. The sample data must be averaged and stored referenced to time and/or distance so that the data may be processed into transverse profile data or aligned with the accelerometer data to provide a longitudinal profile.

11. The displacement of the vehicle in the vertical direction used to calculate position shall be sensed using an accelerometer. The DAS must provide hardware and software to amplify and filter/integrate the signal as required to obtain the data required for storage and for further post processing of the required data.

12. The vehicle will be equipped with infrared sensors to allow the operational system to perform system functions (start test, end test, reset DMI value, etc.) without operator intervention when using roadside targets.

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