1. SCOPE

1.1. This test method covers the measurement of pavement profile and roughness using a Light Weight Profiler (LWP) 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.

2. REFERENCED DOCUMENTS

2.1. ASTM Adjunct
    E950/E950M Standard Test Method for Measuring the Longitudinal Profile of Traveled Surfaces with an Accelerometer Established Inertial Profiling Reference

2.2. NCHRP Report 228

2.3. Light Weight Profiling System Calibration Verification and Operator Certification Program Manual

2.4. ASTM E1926 Standard Practice for Computing International Roughness Index of Roads from Longitudinal Profile Measurements

2.5. AASHTO R 56
    Standard Practice for Certification of Inertial Profiling Systems

2.6. AASHTO R 57-14
    Standard Practice for Operating Inertial Profiling Systems

2.7. SOL 481-12-03 Implementation of Verification Process for Ride Quality of Newly Constructed Pavements

2.8. PennDOT 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. 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. 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.

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. 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 the "Generic Specification for Light Weight Profiling System," Appendix A. (Disregard Items 11 and 12 of Appendix A, which refer to equipment supplier obligations, and note that Item 13 is optional). All manufactured equipment must be capable of providing electronic files in ProVAL compatible format. Approved manufacturers must supply PennDOT’s Bureau of Maintenance and Operations, Pavement Testing and Asset Management Section with a copy of the processing and analysis software.

4.2. Acceptance

4.2.1. Prior to testing, the LWP device must be checked to verify that it has been calibrated and is operating properly. The operator of the LWP device must be certified by the Bureau of Maintenance and Operations, Pavement Testing and Asset Management Section.
4.2.1.1. Accepted profilers will be 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.

4.2.1.2. Additional re-verification/re-certification 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.

4.2.1.3. Certified operators will receive individual certification cards that are valid for up to three calendar years.

4.2.1.4. Verification/certification will be done in accordance with the Light Weight Profiling System Calibration Verification and Operator Certification Program Manual.

4.3. Software

4.3.1. The test software must activate the testing using the timing and control parameters stored by the test control setup software. The software must monitor the signals to verify that the testing is being performed properly and indicate detectable errors.

4.3.2. The test software must receive, display, and store raw data received from the vehicle mounted transducers at corresponding distances and test speeds.

4.3.3. The system must be capable of meeting the requirements of Appendix A.

4.3.4. The operator of a certified LWP must use the same software version and settings on PennDOT projects that were used during the profiler certification.

4.3.5. Changes to the software version may result in re-verification or re-certification of the profiler.

5. CALIBRATION

5.1. A distance sensor calibration must be performed each day that the LWP device is in use, prior to any measurements used to determine pavement ride quality for acceptance and payment.

5.1.1. 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. 5 feet per mile (or 1 ft. per 0.20 mile), accuracy is required.

5.1.2. 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.

5.1.3. No more than one single certified operator is to occupy the profiler during calibration, as per equipment specifications.

5.2. Laser height verification (e.g., gauge block check) must be performed in accordance with AASHTO R 57-14 or the manufacturer’s recommended procedures each day the LWP device is in use, prior to any measurements used to determine pavement ride quality for acceptance and payment. The laser height must be +/- .02 inches.

5.2.1. A full verification check of the laser sensors must also be performed as described in Section 5.2 whenever problems are suspected.

5.3. Accelerometer verification must be performed in accordance with the manufacturer’s recommended procedures each day the LWP device is in use, prior to any measurements used to determine pavement ride quality for acceptance and payment. The tolerance for the accelerometer verification must meet the manufacturer’s requirements.

5.4. 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 any measurements used to determine pavement ride quality for acceptance and payment. The IRI for bounce will be less than or equal to 15 inches per mile.

5.5. 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.

5.6. 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.

6. PROCEDURE

6.1. Startup and initialization.
6.1.1. Clear the intended LWP path of all loose material and foreign objects.

6.1.2. Perform all necessary start up procedures.

6.1.3. Verify that distance measurement, sensors, and accelerometers are properly calibrated. Perform all necessary calibration procedures, as specified in Section 6, and as per equipment manufacturer procedures. Save all values.

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

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

6.2. Sampling

6.2.1. 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.

6.2.2. Measure profiles to the limits of the pavement areas, as specified. As per the Specifications, 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).

6.2.3. 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.

6.3. Data collection

6.3.1. Position the LWP to a point where the testing speed can be reached before testing begins. When possible, it is recommended to collect at least 30 m (100 ft.) of data before the area to be tested, to eliminate all error through filtering in the program that processes the data. When this is not possible, provisions are necessary in the report program to eliminate some of the beginning and/or ending test data to minimize the error.

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

6.3.3. The LWP shall remain stationary to wait for the system filters to stabilize (approximately 1 min).
6.3.4. Start the LWP moving and initiate testing when the LWP reaches testing speed.

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

6.3.6. Continue testing at a consistent speed until the test end point is passed.

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

6.3.8. 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.

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

6.3.10. 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.

6.3.11. Measure IRI for excluded areas separately.

7. PROJECT SITE VERIFICATION

7.1. The Department shall certify all lightweight profilers and operators prior to testing on bituminous or concrete paving projects (including at-grade bridge structures). Certification does not eliminate the need for project verification of the equipment and operator, or daily calibrations of the profiler.

7.1.1. The Project Engineer (or designee) will approve the operator and equipment for project level testing by verifying the equipment and software against the 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. A list of approved contractor operators and approved equipment is posted on Bureau of Maintenance and Operations/Asset Management/Pavement Testing and Asset Management Section/Roadway Inventory and Testing Unit’s webpage.

7.1.2. The Project Engineer will verify the profiler meets the previously stated calibration requirements.
7.1.2.1. The contractor will demonstrate the profiler operation prior to project use.

7.1.2.1.1. The demonstration will consist of an agreed upon known distance measurement on the project; the tolerance for distance is 5 ft. per mile (or 1 ft. per 0.20 mile).

7.1.2.1.2. A height measurement for each wheel path sensor using the calibration gauge blocks shall be made; the tolerance for height is 0.02 inches.

7.1.2.1.3. An accelerometer calibration shall be conducted daily and then as needed per the manufacturer’s requirements.

7.1.2.1.4. A successful bounce test that demonstrates a flat profile shall be conducted daily. The IRI for bounce will be less than or equal to 15 inches per mile.

7.1.2.1.5. All results shall be printed or documented.

8. SUBMITTALS

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

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

8.3. Provide a summary printout of the IRI value calculated for each pass. IRI shall be calculated using a quarter-car simulation as outlined in NCHRP Report 228.

8.4. As required, adhere to SOL 481-12-03, Implementation of Verification Process for Ride Quality of Newly Constructed Pavements and supply the necessary files and PennDOT Contractor IRI Data Collection Form.

8.5. Provide a USB flash drive or CD that contains the raw (unfiltered) binary data and raw (unfiltered) ERD files collected for each wheel path so that PennDOT may perform subsequent analysis. In addition, a hard copy report must be provided for each wheel path. Each pass shall be clearly labeled so PennDOT personnel can easily identify the file data. Identification information includes County, State Route, Project Number, Lot Number, and Wheel path.

8.6. As a minimum, the following information must be printed 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: the version number or identification of the LWP device operational system
(8) Data filter settings
(9) High-pass filter setting = 100 ft.
(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

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) a height sensor which measures the distance between a vehicle reference point and the pavement while the vehicle is driven over the roadway.

(2) an accelerometer which measures the vertical acceleration of the vehicle as it bounces in response to the road profile.

(3) a distance sensor which provides a reference measurement of the vehicle as it traverses the pavement.

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. After the post processing software is utilized, the measured profiles must show variations in elevation and slope as they affect roughness. In addition, profile plots must be capable of being displayed on a computer screen or on hard copy after post processing. The system must obtain and store profile measurement data at selected longitudinal distance intervals of one reading per approximately 1 in (25 mm).

3. 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 "in./mi." 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 rod and level survey equipment. 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.

4. 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) RN/PI computation
   (3) IRI computation
   (4) high-pass filtering
   (5) low-pass filtering (smoothing)
   (6) height sensor error checking

5. 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. The post processing software must be capable of running on a Windows based PC with a Super Visual Graphics Array (SVGA) or better monitor where graphics are used.
6. 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 and Event 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.

7. 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.

8. 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 ft. above the pavement surface. The laser or infrared module shall be equivalent to a Selcom sensor, which has a resolution of 0.001 in. 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.

9. 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 into the required data.

10. Upon delivery of the system, the equipment supplier must provide a complete description of the format of all files generated by the software, such that data files can be prepared on disks in a format necessary for the software to read and process all of the items defined in Item 4.

11. Upon delivery of the system, the equipment supplier must also provide:

   (1) One copy of operating procedures for all operational software.
   (2) One copy of schematics, block diagrams and wiring diagrams covering electronic circuitry of the installed system.
   (3) One complete parts list detailing the components of all equipment used.
   (4) A three day training session on the use of the new equipment, and a one day training session on data reduction.

12. The equipment supplier must warrant all components of the operational system for a period of not less than one (1) year from the date of acceptance to be free from defects in material and workmanship.
The following item is optional:

13. 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.