Florida Method of Test
for
Measuring Pavement Longitudinal Profiles Using a Laser Profiler

Designation: FM 5-549

1. SCOPE

1.1 This method covers the measurement of pavement surface profiles using a laser profiler.

1.2 This test method utilizes a pavement surface record generated along the individual wheel paths using a laser-equipped vehicle traveling at highway speeds. Such a record is analyzed to determine the rate of roughness (or smoothness) and to identify changes in the longitudinal pavement surface elevation that exceed a specified threshold along the pavement length traversed by the instrumented vehicle.

2. APPLICABLE DOCUMENTS

2.1 ASTM E-177 - Recommended practice for use of the terms precision and accuracy as applied to measurement of a property of a material.

ASTM E-178 - Recommended practice for dealing with outlying observations.

ASTM E-950 - Standard test method for measuring the longitudinal profile of traveled surfaces with an accelerometer establishing inertial profiling reference.

ASTM E-1274 - Standard test method for measuring pavement roughness using a profilograph.

ASTM E-1489 - Standard practice for computing Ride Number of roads from longitudinal profile measurements.

ASTM E-1926 - Standard practice for computing International Roughness Index of roads from longitudinal profile measurements.

World Bank Technical Paper Number 45 - The International Road Roughness experiment establishing correlation and a calibration standard for measurements.

World Bank Technical Paper Number 46 - Guidelines for conducting and calibrating road roughness measurements.

Federal Highway Administration Order 5600.1A, Appendix J.

3. SUMMARY OF METHOD

The test apparatus consists of three laser sensors mounted in the front of a specially designed bumper of a full-sized van. Two of the sensors are mounted 69 inches apart and equidistant from the bumper centerline to measure pavement profiles in the two wheel paths of the traveled surface. The third sensor is located exactly at the bumper centerline. The test apparatus also uses two accelerometers mounted with the outward sensors to isolate vehicle motion. The vehicle is also equipped with a data acquisition system to collect and store elevation profile data of the traveled surface. A distance-measuring instrument is provided to monitor the traveled distance.

The sampling rate is selected based on the ride parameter requirements for the intended data processing.

The vehicle is driven along the wheel tracks or in the desired position along the pavement section to be tested. While the vehicle is driven at highway speed, the sensors measure the vertical acceleration of the vehicle and the vertical distance between the accelerometer and the pavement surface as well as the traveled distance. These sensor signals are combined through a computerized process to generate the longitudinal profile of the traveled pavement surface.

Note 1: If the vehicle speed drops below 15 MPH, all the subsequent profile data shall not be considered in determining the ride characteristics of the traveled pavement section.

3.4 The International Roughness Index (IRI) and the Ride Number (RN) are determined in accordance to ASTM E-1926 and ASTM E-1489, respectively. In addition, for the purpose of the present procedure, all the raw ride data used in computing IRI and RN is filtered to a 300 ft wavelength.

4. SIGNIFICANCE AND USE

4.1 This test method provides a means for evaluating the ride characteristics of new, rehabilitated, or in-service pavements directly from measured surface profiles. The resulting ride quality is quantified in terms of IRI and/or RN.

4.2 The measured ride values represent roughness obtained with the equipment and procedures stated herein and do not necessarily agree or correlate directly with those obtained by other methods.

5. APPARATUS

5.1 The test apparatus consists of a full-sized van equipped with a specially designed bumper to house the laser sensors and accelerometers. This

bumper houses three laser sensors and two accelerometers. The vehicle is also equipped with a data acquisition/display system and a distance-measuring instrument.

5.2 All electronic and mechanical components of the profiling system shall be adequately designed to withstand adverse conditions such as dust, moisture, vibrations, and shocks that may be encountered during testing.

5.3 All the measuring instruments must comply with the standard set forth in ASTM E-950 to classify the profiling equipment as Class 1. The resolution of the vertical measurement shall not be more than 0.005 inch (0.1 mm). The accelerometer range must be large enough to accommodate the levels of acceleration expected from bounce motions of the measuring vehicle (typically ±1 g). In addition, the distance measuring device must produce a sufficient series of pulses, the intervals of which represent a distance along the traveled surface (longitudinal sampling) to a resolution of less than or equal to 1.0 inch (25 mm). Also, the data acquisition system must be of sufficient speed and capacity and provides printed and digital display of the above sensors outputs.

6. SAFETY PRECAUTIONS

6.1 The test vehicle, as well as all attachments to it, shall comply with applicable State and Federal laws. All precautions shall be taken beyond those imposed by law to insure the safety of operating personnel and the public. No testing shall be conducted when dangerous conditions exist.

7. CALIBRATION

7.1 Calibration Test Sections – The pavement sections used to calibrate the test speed indicator and the distance-measuring instrument shall be level and straight sections of at least 1.0 mile (1.6 km) in length. The length of each of these sections used for this type of calibration purposes must be accurately determined.

Where pavement sections are used for calibration of profiling sensors and accelerometers, these sections shall be uniform in roughness throughout, and, as far as practical, tangent with only minimal grade. Each section should be a minimum of 0.3 mile (0.48 Km) in length. The first and last 0.1 mile (0.16 Km) segments shall be considered as the approach and leave areas, respectively. The middle 0.1-mile (0.16 Km) shall be used for calibration.

All the calibration sections shall not include bridge structures, railroad crossings, or intersections. The surface should be free of debris prior to testing.

7.2 Speed – The test speed indicator shall be calibrated by determining the time required to traverse an accurately measured length of a leveled and straight pavement section at a constant speed. Calibration speeds should encompass the normal speed (or speeds) required for testing. A minimum of three test runs at each test speed should be made for calibration. The measured accuracy should be within ±2 miles per hour (3.2 Km per hour) of the average test speed.

7.3 Distance – The distance-measuring instrument output is calibrated by determining the distance recorded after traversing an accurately measured, level and straight pavement section. The measured accuracy should be within ± 0.1 percent.

7.4 Roughness - Prior to calibration, caution should be exercised to ensure proper operation of all electronic and mechanical equipment. All operations should comply with the manufacturer's recommended procedures. The calibration consists of electronically calibrating the laser sensors for alignment, performing bounce test on accelerometers, performing plate calibration to verify accuracy of vertical distance measurement on laser sensors, traversing test sections to assure proper operation, and comparing profile outputs to other Class 1 profilers.

7.5 Frequency - The calibration section should be verified on an annual basis. The equipment should be evaluated on a monthly basis. However, a calibration check should be made any time it is felt the validity of the test apparatus data is in question.

8. GENERAL

8.1 Equipment relative to profiling quality of the test vehicle and the recording system should be inspected prior to initiating any tests.

8.2 All the raw profile data is processed using a 300-ft wavelength filtering to determine the International Roughness Index (IRI_{300F}) and/or Ride Number (RN_{300F}).

8.3 For ride acceptance purposes of new and/or rehabilitated pavement sections, the profile data is collected at Rate 2 (as-collected profile data is averaged in 6-in. (152-mm) intervals). The collected data is then analyzed to determine RN_{300F} in 0.1-mile (0.16 Km) pavement segments (lots). The reported ride numbers (RN_{300F}) for each pavement segment or lot are the average ride values as collected on the left and right wheel paths for the corresponding segment.

Note 2: The profile data is analyzed in 0.1 Km (0.62 mile) pavement segments (lots) for projects requiring metric units.

Note 3: When applicable, the Department defines acceptable values of roughness for new construction and overlays in the contact special provisions. Since pavement and roadway system types as well as the traffic volume could influence the required ride characteristics, different target limits may be specified from one project to another.

Note 4: Incentive and/or disincentive payments shall adhere to the specific project specifications and/or Supplemental specifications.

8.4 When the profiling is conducted as part of the Pavement Condition Survey (PCS), one pass at rate 4 (as-collected profile data is averaged in 1-foot (0.305 m) intervals) is usually adequate to determine the ride characteristics of a pavement section. The profile data from each wheel paths is then analyzed to determine the IRI_{300F} and RN_{300F}, respectively. RN_{300F} is converted to ride rating on 0 to 10 scale for pavement management purposes by using a multiplying factor of 2.

Note 5: The PCS sections are those defined as sections of uniform composition and age. Construction limits, County sections and subsections, significant changes in condition or existence of structures longer than ¼ mile typically establish section survey limits.

8.5 When testing is conducted as part of the Highway Performance Monitoring System (HPMS), the ride data is also collected at Rate 4. The ride data as collected from the right wheel path only is then analyzed to determine and report the IRI_{300F} values.

Note 6: The HPMS sections are defined as those roadway sections randomly selected by the Central Planning Office. The testing on these sections is conducted in compliance with the Federal Highway Administration Order M5600.1A, Appendix J.

8.6 All the profile testing on experimental and research projects is conducted a Rate 4. The ride data is analyzed to determine both IRI_{300F} and RN_{300F} values.

8.7 The testing shall be conducted with the test vehicle tires centered in the normal traffic pattern (wheel paths). The testing speed shall be consistent, when possible, and within the requirements of the posted speed limits. In all instances, the testing speed shall not exceed a 60 MPH limit.

8.8 The profile testing should be conducted when the ambient temperature is between 40 and 100^{o} F (5 and 38^{o} C).

9. PROCEDURE

9.1 Bring the test vehicle to the desired speed and alignment prior to beginning test sections. Speed should be maintained as constant as possible throughout the test.

Record the data pertinent to the test.

Test results that are manifestly faulty shall be discarded according to ASTM Recommended Practice E 178. Individual determinations of roughness for a test result average shall conform to Section 12.

10. CALCULATIONS

10.1 Determine test section location, length and limits.

10.2 Determine the desired test value (IRI, RN, PSI, etc.) that represents the pavement section tested.

10.3 Calculate the value for pavement roughness in accordance to the project requirements.

10.4 Testing can not be accomplished if pavement is damp.

11. REPORTS

11.1 Field Report - The field report for each section shall include the following items:

11.1.1 Location and identification of test section.

11.1.2 Date and time of day.

11.1.3 Weather conditions as necessary (temperature, wind).

11.1.4 Type of pavement.

11.1.5 Lane tested.

11.1.6 Speed of test vehicle.

11.1.7 Test value.

11.1.8 Operator.

11.2 Summary Report - The summary report for each test section shall include data on the following items insofar as they are pertinent to the variables under investigation:

11.2.1 Location and identification of test section.

11.2.2 Lane tested.

11.2.3 Date of test.

11.2.4 Pavement type.

11.2.5 Test results.