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Standard Test Method for Measurement of Vehicular Response to Traveled Surface Roughness[1]

This standard is issued under the fixed designation E 1082; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the determination of vehicular response to traveled surface roughness.

1.2 This test method utilizes an apparatus that measures the relative motion of a sprung mass system in response to traveled surface roughness where the mass is supported by automotive type suspension and tires.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* Specific precautionary statements are given in Section 6.

2. Referenced Documents

2.1 *ASTM Standards:*

E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods[2]

E 178 Practice for Dealing with Outlying Observations[2]

E 867 Terminology Relating to Traveled Surface Characteristics[3]

E 1136 Specification for a Radial Standard Reference Test Tire[3]

3. Summary of Test Method

3.1 Vehicular response to traveled surface roughness is calculated from an accumulated displacement measurement divided by the test section length. A vehicle is brought to the desired test speed and lateral position in the lane to be tested. The test apparatus is placed in operation and a constant speed is maintained throughout the test. Pertinent information affecting test results must be noted.

4. Significance and Use

4.1 This test method provides a means of evaluating traveled surface roughness. The measured values represent vehicular response to traveled surface roughness obtained with the equipment and procedures stated herein and do not necessarily agree or correlate directly with those obtained by other methods.[4]

5. Apparatus

5.1 *Test Apparatus*, consisting of an axle to frame the displacement measuring sensor, a displacement accumulator, a distance measuring system and a recording system mounted in a vehicle that is either a suitable passenger automobile with four wheels or a suitable single axle, twowheel trailer towed by a vehicle.

5.2 *Test Automobile*—The vehicle used to house the displacement measurement sensor. It shall be equipped as follows:

5.2.1 Engine in front,

5.2.2 Rigid rear axle,

5.2.3 Rear springs (coil, single leaf, gas),

5.2.4 Rear sway bar,

5.2.5 Heavy duty shock absorbers,

5.2.6 Tires dynamically balanced (GM-TPC[5]or Specification E 1136),

5.2.7 Cruise control[6], and

5.2.8 Air conditioning.[6]

5.3 *Test Trailer*—A two-wheel trailer shall be specifically designed and equipped to house the displacement measurement sensor, meeting the following requirements:

5.3.1 120 ± 1 in. (3048 ± 25 mm) from the center of the hitch to the center of the axle,

5.3.2 65 ± 5 in. (1651 ± 127 mm) from the center of the tire to the center of the tire,

5.3.3 Coil spring-shock-absorber suspension system,

5.3.4 Sway bar,

5.3.5 Tires dynamically balanced (GM-TPC[5]),

5.3.6 Weight and suspension system balanced to provide a response to the range of traveled surface roughness to be measured, and

5.3.7 Rigid axle.

5.4 *Instrumentation*:

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[1] This test method is under the jurisdiction of ASTM Committee E-17 on Vehicle-Pavement Systems and is the direct responsibility of Subcommittee E17.31 on Methods for Measuring Profile and Roughness.

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[2] *Annual Book of ASTM Standards*, Vol 14.02.

[3] *Annual Book of ASTM Standards*, Vol 04.03.

[4] Gillespie, T. D., Sayers, M. W., and Segel, L., "Calibration of Response-Type Road Roughness Measuring System," *National Cooperative Highway Research Program Report 228*, December 1980.

[5] General Motors, "Tire Performance Criteria, Procedures and Specifications," *Engineering Publication A-4082*, General Motors Corp., Milford, MI, 1982.

[6] These items are optional but are listed since they can substantially affect the ease with which the test is run.

5.4.1 *General Requirements*—The instrumentation shall function accurately at ambient temperatures between 40°F and 100°F (4.4°C and 37.8°C). All electronic and mechanical components of the system will be adequately designed to withstand adverse conditions such as dust, moisture, vibrations, and shocks that may be encountered in traversing the traveled surfaces to be measured.

5.4.2 *Displacement Measuring Sensor*—Capable of measuring relative vertical axle-to-frame displacement in increments of 0.125 in. (3.175 mm) or less in response to traveled surface roughness.

5.4.3 *Displacement Accumulator*—Capable of accumulating the output of the displacement measurement sensor in one or both directions and transmitting an output, which is a function of the measured displacement, to the recording system.

5.4.4 *Distance Measuring System*—Must indicate distance by producing an output directly proportional to traveled distance that will actuate a high-speed counter capable of accepting count rates equivalent to the highest possible test speed. The system shall accommodate measurements in either feet or miles (metres or kilometres) and have calibration adjustment capability.

5.4.5 *Recording System*—Must provide an accumulative graphic, printed, or digital display of the outputs of the displacement accumulator and distance measurement system.

6. Safety Precautions

6.1 The test vehicle, as well as attachments to it, shall comply with applicable state and federal laws. Precautions imposed by law shall be taken to ensure the safety of operating personnel and the public.

7. Calibration

7.1 *Speed*—Calibrate the vehicle speedometer that is used to indicate the test speed by determining the time required to traverse an accurately measured (±0.1 %), level and straight section of pavement at a constant indicated speed. Calibration speeds should encompass the normal speed (or speeds) required for testing. A minimum of three test runs at each speed should be made for calibration. The precision of measured distance/time for the three test runs should be within ±2 mph (±3.2 km/h) of the average. The tangent section of pavement used for this calibration should be at least 0.5 mile (0.8 km) in length.

7.2 *Distance*—Calibrate the distance output by determining the distance recorded after traversing an accurately measured (±0.1%) level, tangent pavement section at a constant indicated speed. Distance calibrations should incorporate all calibration speeds. A minimum of three test runs should be made at each speed. The precision of the distance output for the three test runs should be within ±1 % of the average. The tangent section of pavement used for this calibration should be at least 1.0 mile (1.6 km) in length.

7.3 *Vehicular Response to Traveled Surface Roughness*—Prior to calibration, exercise caution to ensure proper operation of all electronic and mechanical equipment. Operation should comply with the manufacturer's recommended procedures and the requirements of this test method. Calibration shall consist of adjusting the output of the displacement accumulator of a particular test apparatus through mathematical or mechanical means to correspond to a measure of roughness determined by one of the following reference methods, selected by the individual agency.

7.3.1 *Preferred Method*[4]—A computer simulation of vehicular response based on inputs from a profile measuring system.

7.3.2 *Alternate Methods*—The following methods of calibration will not necessarily produce results that are in agreement with the preferred method or with each other:[4]

7.3.2.1 A measure of roughness of the CHLOE[7] profilometer,

7.3.2.2 Artificial roughness surfaces,

7.3.2.3 Panel rating, and

7.3.2.4 A similar piece of equipment calibrated as a standard.

7.3.3 *Pavement Calibration Sections*—Pavement sections (not to include artificial roughness surfaces) used for the calibration of vehicular response to traveled surface roughness shall be uniform in roughness throughout, as far as practical, and shall be a minimum of 0.2 miles (0.3 km) in length.

7.3.3.1 A minimum of three pavement sections should be used for calibration of vehicular response to traveled surface roughness. These sections shall exhibit roughness within a range of values significant for routine testing.

7.3.3.2 A separate calibration of vehicular response to traveled surface roughness will be required for each test speed. A minimum of three determinations of vehicular response to traveled surface roughness shall be required for each particular test speed. The calibration of vehicular response to traveled surface roughness at different speeds will enable testing at a speed appropriate to the flow of traffic.

7.4 *Frequency*—The calibrations are valid only if no changes occur or are made in the test apparatus. The individual agency shall set the frequency of calibration and calibration checks. The recommended minimum frequency of calibration is annual.

8. Test Preparation

8.1 Equipment which has an effect on the riding quality of the vehicle and the instrumentation should be inspected prior to initiating the testing. Tires and shock absorbers should be in good condition. Prior to each series of tests, warm up the tires by traveling for at least 5 miles (8 km) at normal traffic speeds. Set the tire inflation pressure at the tire manufacturer's maximum recommended pressure for size and type of tire used at ambient temperature just before the 5 mile (8 km) warmup.

8.1.1 *Automobile Mounted Units*—These units are sensitive to the following, and special attention must be given to these items prior to testing to ensure that they are in the same condition as when the test apparatus was calibrated:

8.1.1.1 Total mass of the vehicle and its contents,

8.1.1.2 Number of vehicle occupants,

8.1.1.3 Mass distribution within the vehicle,

[7] "The AASHO Road Test, Report 5, Pavement Research," *HRB Special Report 61E*, 1962.

8.1.1.4 Wheelbase (same vehicle),

8.1.1.5 Type and condition of the shock absorbers and the springs,

8.1.1.6 Tire type, condition, balance and pressure,

8.1.1.7 Test speed,

8.1.1.8 Fuel quantity of one-half tank, minimum, and

8.1.1.9 Front-end suspension condition and alignment.

8.1.2 *Trailer Mounted Units*—These units are suggested because of the obvious elimination of many of the variables in 8.1.1. However, special attention must be given to ensure that the items in 8.1.2.1-8.1.2.3 are in the same condition as when the test apparatus was calibrated.

8.1.2.1 Tire condition, balance, and pressure,

8.1.2.2 Shock absorbers and spring condition, and

8.1.2.3 Test speed.

9. Test Sections

9.1 The test sections should be continuous sections of traveled surface (construction projects) of uniform age and composition, that have been subjected to essentially uniform wear. The individual agency shall specify the minimum test section length but not less than 0.1 mile (0.2 km). Each lane should be considered a separate test section. Test sections shall not include bridge structures or railroad crossings. The surface should be free of debris prior to testing.

9.2 *Lateral Positioning of Test Vehicle on Test Sections*—Normal testing shall be accomplished with the test tires centered in the normal traffic pattern (wheelpaths).

10. Test Speed and Temperature

10.1 *Test Speed*—Should correspond with one of the calibration speeds consistent with the posted speed limit.

10.2 *Test Temperature*—Ambient temperature should be between 40°F and 100°F (4.4°C and 37.8°C).

11. Measurement

11.1 *Significance of Measurements*—The individual agency should define acceptable values of vehicular response to traveled surface roughness for existing pavements, new construction, and overlays. The pavement type and traffic are influencing characteristics which may require different values.

11.2 *Vehicular Response to Traveled Surface Roughness*—Shall be expressed in common terms which do not fluctuate with test section length. (Example: units of axle displacement per unit length).

12. Procedure

12.1 Prior to the beginning of the test section, bring the test vehicle to the desired speed and alignment and maintain constant speed throughout. A variation in the indicated speed of ±2 mph (±3.2 km/h) will void the acquired data.

12.2 Record the data pertinent to the test.

12.3 Individual determinations of vehicular response to traveled surface roughness for a test result average shall conform to Section 12. Test results that are manifestly faulty shall be discarded in accordance with Practice E 178.

13. Calculation

13.1 Determine the test section limits and length.

13.2 Determine the accumulated displacement in response to traveled surface roughness measured within the test section limits.

13.3 Calculate the test result of vehicular response to traveled surface roughness as necessary, dependent upon the method of calibration used.

14. Report

14.1 *Field Report*—The field report for each test section shall contain data on the following items:

14.1.1 Location and identification of test section,

14.1.2 Date and time of day,

14.1.3 Ambient temperature,

14.1.4 Type of pavement,

14.1.5 Lane tested,

14.1.6 Speed of test vehicle,

14.1.7 Test result from 13.3,

14.1.8 Operator(s),

14.1.9 Test unit identification, and

14.1.10 Calibration method (optional).

14.2 *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:

14.2.1 Location and identification of the test section,

14.2.2 Lane tested,

14.2.3 Date of test,

14.2.4 Pavement type,

14.2.5 Test result, and

14.2.6 Calibration method.

15. Precision and Bias

15.1 *Individual Measurement Precision*—Individual repeated determinations of accumulated displacement for the same test section by the same operator with the same equipment on the same day must agree with the average of the determinations of accumulated displacement within ±10 % (2S %) as defined in Practice E 177 or should be considered suspect. This precision statement is based on data from 0.5 mile (0.8 km) test sections. The precision may vary with the test section length. No further data is available at this time to make an additional statement on precision. The individual agency must set the number of determinations of vehicular response to traveled surface roughness necessary to achieve the precision desired. Normally, three determinations will be required for a given test section.

15.2 *Bias of Test Results*—Since there is not a single agreed on or accepted method of calibration, no statement on bias can be made at this time.