Designation: E 445/E445M – 88 (Reapproved 1996)

AMERICAN SOCIETY FOR TESTING AND MATERIALS
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Standard Test Method for Stopping Distance on Paved Surfaces Using a Passenger Vehicle Equipped With Full-Scale Tires[1]

This standard is issued under the fixed designation E 445/E445M; 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 measurement of stopping distance on paved surfaces with a passenger vehicle equipped with specified full-scale automobile tires.

1.2 This test method utilizes a measurement of stopping distances representing the non-steady state skid resistance on four locked wheels as the vehicle decelerates over a wetted pavement surface under specified limits of static wheel load and from a desired speed, while the vehicle remains essentially parallel to its original direction of motion.

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.4 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems 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.*

2. Referenced Documents

2.1 *ASTM Standards:*

E 178 Practice for Dealing with Outlying Observations[2]

E 274 Test Method for Skid Resistance of Paved Surfaces Using a Full-Scale Tire[3]

E 501 Specification for Standard Rib Tire for Pavement Skid-Resistance Tests[3]

F 403 Test Method for Tires for Wet Traction in Straight-Ahead Braking, Using Highway Vehicles[4]

F 457 Method for Speed and Distance Calibration of a Fifth Wheel Equipped with Either Analog or Digital Instrumentation[4]

3. Summary of Test Method

3.1 The test apparatus consists of a passenger vehicle with four wheels.[5] The apparatus contains transducers, instrumentation, and a brake system for the four test wheels. The test wheels are equipped with ASTM Pavement Test Standard Tires as specified in Specification E 501.

3.2 The pavement in the test lane is wetted. The test vehicle is brought above the desired test speed and is permitted to coast onto the wetted section until the proper speed is attained. The brakes are then promptly and forcefully applied to cause a quick lockup of the wheels and to skid to a stop. The resulting distance required to stop is recorded with the aid of suitable instrumentation, and the speed of the test vehicle at the moment of brake application is noted.

3.3 The skid resistance of the paved surface is determined from the resulting stopping distance measurement and test speed as stopping distance number, SDN, as determined from the equation given in 9.1, or as stopping distance, SD.

NOTE 1—Since speed has a significant effect on pavement surface skid resistance measurements, ranking and comparison of pavement surfaces at higher speeds might be considerably different from that at lower speeds.

4. Significance and Use

4.1 The knowledge of vehicle stopping distance serves as an additional tool in characterizing the pavement surface skid resistance. When used in conjunction with other physical and chemical tests, the skid resistance values derived from this test method may determine the suitability and adequacy of paving materials or finishing techniques. Improvements in pavement maintenance practices and schedules may result from use of this test method.

4.2 The stopping distance values measured by this test method with the equipment and procedures stated herein do not necessarily agree or correlate directly with other methods of skid-resistance measurements.[6,7] This test method is suitable for research and development purposes, where direct comparison between pavement surfaces are to be made within the same test program.

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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 E17.21 on Field Methods for Measuring Tire Pavement Friction.

Current edition approved Feb. 1, 1988. Published March 1988. Originally published as E 445 – 71 T. Last previous edition E 445 – 82.

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

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

[4] *Annual Book of ASTM Standards*, Vol 09.02.

[5] Rizenbergs, R. L., and Ward, H. A., "Skid Testing With an Automobile," *Record No. 187, Highway Research Board*, 1967.

[6] Rizenbergs, R. L., "Florida Skid Correlation Study of 1967-Skid Testing with Automobiles," *Highway Skid Resistance, ASTM STP 456*, ASTM, 1969.

[7] Dillard, J. H., and Mahone, D. C., *Measuring Road Surface Slipperiness, ASTM STP 366*, ASTM, 1965.

5. Apparatus

5.1 *Vehicle*—A four-wheel passenger vehicle or a light truck preferably equipped with a heavy-duty suspension system.

5.1.1 *Braking System*—The four test wheels shall be equipped with suitable brakes. The brake system shall be capable of rapidly locking the wheels and maintaining the locked-wheel condition throughout the test.

5.1.2 *Wheel Load*—The static wheel load of the vehicle shall not exceed the rated load of the ASTM Pavement Test Standard Tire in accordance with Specification E 501, and shall be as close to the stipulated load as possible. The vehicle gross weight shall not be less than 3200 lb [1.45 mg].

5.1.3 *Tire and Rim*—The test tires shall be the ASTM Pavement Test Standard Tire as specified in Specification E 501 mounted on a 15 by 6 JJ rim.

5.2 *Instrumentation*:

5.2.1 *Vehicle Speed-Measuring Transducer and Indicator*—The transducer shall be a "fifth wheel"-mounted tachometer generator or transducer. The speed-indicating meters shall provide speed resolution and accuracy of ±1.0 mph[±1.5 km/h]. Output shall be directly viewable by the operator and recorded if desired. The slewing rate of the fifth wheel shall be within the limits described in Test Method F 403.

5.2.2 *Distance-Measuring Transducer and Counter*—A "fifth-wheel"-mounted transducer, producing at least 1 count per foot [3 counts per metre], shall actuate a high-speed distance counter capable of accepting a count rate equivalent to the number of counts produced at the selected test speed, or the transducer output shall be recorded.

NOTE 2—The fifth wheel assembly with speed and distance readouts should meet requirements specified in Method F 457.

5.2.3 *Pressure-Sensitive Switch*—A pressure-sensitive switch, such as a hydraulic brake-light switch, requiring 70 to 90 psi [480 to 620 kPa] pressure to close, shall be installed in the wheel hydraulic brake system to actuate the stopping-distance counter.

6. Calibration

6.1 *Speed*—Calibrate the test-vehicle speed indicator at the test speed by determining the time for traversing at constant speed a reasonably level and straight, accurately measured pavement at least 0.5 mile [0.8 km] in length. Make a minimum of two speed determinations at the test speed. The speed shall be accurate to within ±1 mph [±1.5 km/h] and repeatable to within ±2 mph [±3.0 km/h] when calibrated at 40 mph [65 km/h].

6.2 *Distance*—Calibrate the distance transducer and counter by traversing at the approximate test speed a reasonably level and straight, accurately measured pavement at least 0.5 mile [0.8 km] in length. Initiate the calibration from a complete stop at the beginning of the test course and terminate it by stopping at the end of the test course. Distance counter over 0.5-mile [0.8-km] test course shall be within ±3.0 ft [±1.0 m] and repeatable to within a range of ±4.0 ft [±1.2 m] when calibrated at 40 mph [65 km/h]. Perform a minimum of two distance calibrations.

6.3 *Pressure-Sensitive Switch*—Select a pressure-sensitive switch responding to the specified pressure by testing in a hydraulic system equipped with a calibrated pressure transducer or gage having an accuracy of ±3 % of the applied pressure.

7. General

7.1 *Test Vehicle*—Condition new tires by running them at rated inflation pressure on the test vehicle (or a similar vehicle) at a maximum speed of 50 mph [80 km/h] for a distance not less than 200 miles [320 km] before they are used for test purposes. After conditioning, dynamically balance all tire and wheel assemblies. Inspect the tires for flat spots, damage, or other irregularities that may affect test results, and reject tires that have been damaged or worn beyond the wear line. The tire inflation pressure shall be 24 ± 0.5 psi [165 ± 3.5 kPa] at ambient temperature (cold). Prior to each series of tests, warm-up the tires by traveling for at least 5 miles [8 km] at normal traffic speeds.

7.2 *Test Sections*—Test sections shall be defined as segments of the highway having a pavement of uniform age and uniform composition that has been subjected to essentially uniform wear along its length. For instance, do not include sharp curves and steep grades in the same test section with level tangent sections, and do not include passing lanes with traffic lanes. Make stopping distance measurements only on pavements that are free of obvious or unusual contamination.

7.3 *Test Sites*—Test sites shall be defined as segments of test sections selected for stopping distance measurement, and shall include traffic lanes, or passing lanes, in both directions of travel.

7.4 *Lateral Positioning of Test Vehicle on Highway*—Normally, perform test in the center of the wheel tracks of a traffic lane of a highway. A stopping distance number may be quoted without qualification only if the test vehicle was so positioned during the test. If during the test, the vehicle moves outside the wheel tracks for more than 20 % of the stopping distance, or terminates skidding off of the test lane, void the test. If testing cannot be conducted in the prescribed manner, identify the test data accordingly.

7.5 *Test Speed*—The standard test speed shall be 40 mph [65 km/h]. Tests may be made at other speeds but not less than 20 mph [32 km/h]. Initiate tests within ±1.0 mph[±1.5 km/h] of the desired speed.

7.5.1 When the test speed is 40 mph [65 km/h], it is desirable, but not necessary, to cite the speed when quoting the test data. For all other speeds, including test speeds above 40 mph [65 km/h], the speed must be recorded. This may be done by adding to the symbol as a subscript the numerals of the test speed in mph, that is, SDN_{30}, or SD_{30}, indicates stopping distance number, or stopping distance, at a test speed of 30 mph [48 km/h].

8. Procedure

8.1 *Distance Counter Reading*—Set the distance counter to zero prior to testing and record the total counts accumulated during the skid. If a strip-chart recorder is used for the purpose of measuring stopping distance, the recorded pulses may be counted later, but properly mark the chart or have the brake switch apply a mark to the chart when the switch closes.

8.2 *Pavement Wetting*—Wet the test lane at the test site just

prior to skid testing using a water wagon equipped with spray bar or other means of distributing water evenly and rapidly. Make two or more applications of water with a minimum coverage of 0.015 gal/ft^2 [0.6 L/m^2] ± 15% per application until the surface is well-saturated (surface cavities are filled with water and runoff results). Wet a sufficiently long segment of the test lane to permit the test vehicle to skid on a wet surface and to allow the driver to adjust the speed before brake application. Rewet the test lane between each test as required to maintain similar wetness conditions.

8.3 After the pavement in the test lane is wetted, bring the vehicle above the desired test speed and permit it to coast (transmission gear in neutral) onto the wetted section until the proper speed is attained. Apply the brakes promptly and forcefully to cause quick lockup of the wheels and to maintain a locked-wheel condition until the vehicle comes to a stop. Note the speed at the moment of brake application.

9. Calculation

9.1 Calculate the stopping-distance number for each test as follows:

Inch-pound units:

$$SDN = (V^2/30\ SD) \times 100 \quad (1)$$

Metric units:

$$SDN = [(V^2/255\ SD) \times 100] \quad (2)$$

where:

V = speed of test vehicle at the moment of brake application, mph [km/h], and

SD = stopping distance, ft [m], (total count × feet [metres] per count).

9.2 The test results may also be expressed in terms of stopping distance, SD, in feet (or metres). Stopping distance obtained within the permissible speed deviation may be corrected to the desired test speed by the following equation:

$$\text{Corrected } SD = (\text{desired speed})^2/(\text{actual speed})^2 \times \text{actual } SD \quad (3)$$

10. Number of Tests and Retests

10.1 *Skid Resistance of a Test Section*—Perform at least three measurements of stopping distance in each test lane at a given test site and at each selected test speed. Test no less than two sites in a test section. Consider the arithmetic average of the stopping distance numbers, or stopping distances, to the skid resistance of the test site. Consider the arithmetic average of the determination for test sites to be the skid resistance of the test section. If statistical or other criteria applied to the stopping distance number, for a long test section indicate that it cannot be considered to be uniform, treat the section as two or more sections. For treatment of the results of faulty tests see 10.3.

10.2 *Skid Resistance of a Single Lane*—If the skid resistance of a single lane at a given test site must be known, perform at least six measurements of stopping distance at each specified test speed.

10.3 *Faulty Test*—Tests that are manifestly faulty or that give stopping distance numbers differing by more than 5 SDN from the average of all tests in the same test section shall be treated in accordance with Practice E 178.

11. Reports

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

11.1.1 Location and identification of test sections,

11.1.2 Date and time of day,

11.1.3 Weather conditions, principally temperature, cloud cover, and wind,

11.1.4 Location of each test site and lanes tested,

11.1.5 Test speed (for each test), and

11.1.6 Stopping distance number, or stopping distance (for each test).

11.2 *Summary Report*—The summary report shall include for each test section, data on the following items as far as they are available and pertinent to the variables or combinations of variables under investigation:

11.2.1 Location and identification of test section,

11.2.2 Number of lanes and presence of lane separators,

11.2.3 Grade and alignment,

11.2.4 Pavement type, mix design of surface course, conditions, and aggregate type (specify source if available),

11.2.5 Age of pavement,

11.2.6 Average daily traffic (for each year since pavement construction),

11.2.7 Average traffic speed (or speed mix as in the case of grade with heavy truck traffic),

11.2.8 Date and time of day,

11.2.9 Weather conditions,

11.2.10 Lane tested, and

11.2.11 Average stopping distance number for test section and speed at which reported average was obtained. (Highest and lowest average values for test sites may also be reported; if values are reported that were not used in computing the test section average, this fact shall be recorded).

12. Precision and Bias

12.1 The relationship of observed SDN units to some “true” value of locked wheel sliding friction has not been established at this time. As a result, only repeatability is given for this test method.

12.2 The analysis of available data obtained with an experienced operator indicates that the stopping distance test method shows repeatability or agreement within ±5 % of the average value. Stopping number data obtained with the same operator and under identical test conditions should not be considered suspect unless they differ by more than 5 %.