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Standard Test Method for Measuring the Skid Resistance of Pavements and Other Trafficked Surfaces Using a Continuous Reading, Fixed-Slip Technique[1]

This standard is issued under the fixed designation E2340/E2340M; 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 the skid resistance of a pavement or other trafficked surface using the continuous reading, fixed-slip technique.

1.2 This test method covers braked wheel measurements obtained with less than 100 % slip. It does not cover side force measurements.

1.3 This test method provides a record of the skid resistance along the whole length of one track of the test surface and enables averages to be obtained for specified test segments.

1.4 This test method is used to measure skid resistance on a wide variety of surfaces in a wide variety of circumstances. Consequently, there are many different designs of continuous reading, fixed-slip measuring equipment (CFME) and as many different test procedures governing their use.

1.5 This test method does not attempt to detail these different equipments and procedures but does set out the essential common principles.

1.6 CFMEs function by creating and measuring a frictional force between a test tire operating at a selected slip and the test surface. Different types of CFME do not necessarily create the same frictional force between their particular test tire and a common test surface and do not necessarily use the same method to measure this frictional force.

1.7 CFME measurements are obtained at a selected steady test speed. This speed may vary according to the application.

1.8 The test surface may be contaminated or clean and dry. If it is clean and dry, a measured amount of water is normally deposited on the surface just in front of the test wheel.

1.9 The measuring apparatus may be built into a vehicle, built into a trailer that is towed by a vehicle, or built into a device that is manually pushed.

1.10 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.11 *This standard may involve hazardous materials, operations, and equipment. 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.* Safety precautionary information is contained in Section 7.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E178 Practice for Dealing With Outlying Observations

E501 Specification for Rib Tire for Pavement Skid-Resistance Tests

E524 Specification for Smooth Tire for Pavement Skid-Resistance Tests

E867 Terminology Relating to Vehicle-Pavement Systems

E1551 Specification for Special Purpose, Smooth–Tread Tire, Operated on Fixed Braking Slip Continuous Friction Measuring Equipment

E1844 Specification for A Size 10 × 4–5 Smooth-Tread Friction Test Tire

F408 Test Method for Tires for Wet Traction in Straight-Ahead Braking, Using a Towed Trailer

F457 Test Method for Speed and Distance Calibration of Fifth Wheel Equipped With Either Analog or Digital Instrumentation

3. Terminology

3.1 For definitions of terms used in this test method, refer to Terminology E867.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

3.2 *Definitions:*

3.2.1 *braking force, n*—dynamic instantaneous frictional force acting on the test wheel.

3.2.2 *braking force coefficient (BFC), n*—appropriately filtered mean of a number of instantaneous friction readings over a defined distance.

3.2.3 *braking slip friction, n*—tangential force generated between the test tire and the test surface.

3.2.4 *braking slip ratio, n*—ratio of relative braking slip circumferential speed to identical unbraked wheel circumferential speed, usually defined as a percent.

3.2.4.1 *Discussion*—An equivalent definition is the ratio of the relative braking slip velocity to the horizontal velocity of the wheel axle.

3.2.5 *continuous reading, fixed slip-measuring equipment (CFME), n*—apparatus that can be moved over the test surface at the chosen test speed and includes a test wheel, a system for braking the test wheel, and instrumentation for measuring the resulting frictional force between the test tire and test surface.

3.2.6 *fixed slip, n*—braking system that forces the test wheel to roll at a constant slip or fixed reduction of its free rolling speed.

3.2.7 *frictional force, n*—resistance generated when one surface moves relative to another with which it is in contact.

3.2.8 *instantaneous friction reading, n*—braking force divided by load or equivalently divided by torque on the test wheel (generated by braking force) divided by load times tire radius (moment arm).

3.2.9 *load force, n*—dynamic instantaneous vertical force acting on the test wheel.

3.2.10 *nominal water film thickness, n*—thickness of the film that the water application system is designed to create ahead of the test tire on an entirely smooth test surface.

3.2.11 *rate of water flow, n*—rate at which water is applied to the test surface in front of the test tire.

3.2.12 *reporting length, n*—defined length over which the BFC is calculated.

3.2.13 *standard nominal water film thickness, n*—nominal water film thickness associated with CFME measurements of a particular type of test application to facilitate comparisons between the results of different tests.

3.2.14 *standard test speed, n*—steady test speed associated with CFME measurements of a particular type of test application to facilitate comparisons between the results of different tests.

3.2.15 *test speed, n*—steady test speed associated with CFME measurements.

3.2.16 *water application system, n*—system for depositing a given amount of water in front of the test tire so that it passes between the tire contact area and the test surface.

3.3 *Definitions of Terms Specific to This Standard:*

3.3.1 *certifying calibration, n*—verification of test equipment, calibration equipment (separate or inbuilt), calibration procedures, and equipment operation recommended to be carried out once a year; the procedure records both as found values and adjusted values.

3.3.2 *field calibration, n*—primary force calibration or the equivalent carried out before each test or series of tests by a trained operator using calibration equipment supplied by the manufacturer; this equipment may be built into the CFME.

3.3.3 *friction map, n*—presentation of friction readings obtained down the length of a test surface (typically an airport runway) over a series of selected paths down the surface.

3.3.4 *operational friction testing, n*—measurement of the friction of a surface in response to an operational need and in whatever conditions exist at the time of the test, which may include contamination by ice, snow, slush, or water; these tests do not include the application of water.

3.3.5 *routine friction testing, n*—measurement of the friction of a surface under standardized test conditions that normally includes a standard test speed and a rate of water flow which gives a standard nominal water film thickness.

3.3.6 *test tire, n*—standard tire for pavement friction testing; test tires for routine friction testing shall have a smooth tread.

4. Summary of Test Method

4.1 The test system is moved over the test surface at the chosen test speed with the test wheel, fitted with a test tire, and forced to roll at a particular braking slip ratio.

4.2 If routine friction testing is taking place, the rate of water flow is adjusted to the test speed so that the chosen nominal water film is achieved.

4.3 The braking force or torque is measured (see Terminology E867) and the load is measured, calculated, or assumed to be the same as the dead weight load.

4.4 The instantaneous friction reading is calculated.

4.5 Either the instantaneous friction reading is recorded or the BFC for each friction length is calculated and recorded.

4.6 Test speed (see Test Method F457), rate of water flow, and other essential supporting data are recorded.

5. Significance and Use

5.1 CFMEs are used to measure skid resistance on runways, roads, and various other trafficked surfaces. These tests may comprise operational testing, performed to obtain an immediate assessment of skid resistance in current conditions or routine testing in standardized conditions which include the application of a precise amount of water in front of the test tire.

5.2 Standard test speeds and nominal water film thicknesses are according to national or international agency standards, the type of CFME, and the test application. Some examples of typical applications are given in Appendix X1.

6. Apparatus

6.1 *Basic Measurements:*

6.1.1 The test apparatus shall be equipped with a force transducer to provide a direct measurement of the braking force or a torque transducer to measure the torque on the test wheel generated by this force or both.

6.1.2 The design of the test apparatus shall ensure that unless the average load force acting on the test wheel remains within 1 % of the static wheel load over the reporting length, the apparatus shall be equipped with a force transducer to measure the load force.

6.1.3 The test apparatus shall include a mechanism for measuring test speed and distance traveled.

6.1.4 Unless the test apparatus is to be used solely for operational testing, it shall include a mechanism for measuring rate of water flow.

6.2 *Tolerance for Adverse Conditions:*

6.2.1 The exposed portions of the system shall tolerate 100 % relative humidity (RH) (rain or spray) and all other adverse conditions, such as de-icing chemicals, dust, shock, and vibrations that may be encountered in the type of testing for which the equipment is designed. The suspension system shall minimize the influence of normal pavement roughness on the accuracy and fidelity of the data collection.

6.3 *Accuracy, Resolution, and Stability of Measuring System:*

6.3.1 At outside ambient air temperatures between –40 and 45°C [–40 and 110°F], overall static system measurement accuracy shall be ±1.5 % of full scale.

6.3.2 Certifying calibration or other time stability calibration shall not be required more than once a year unless the measuring system sustains damage requiring significant repair.

6.3.3 If there is a force transducer that provides a direct measurement of the braking force, it shall do so with minimal inertial effects. It is recommended that this transducer provides output directly proportional to force with hysteresis less than 1 % of the applied load up to the maximum expected loading. The mounting of the braking force-measuring transducer shall be such that the effects of cross-axle loading or torque loading shall be less than 1 % of the applied load. The braking force transducer shall be mounted in such a manner as to experience less than 1° angular rotation with respect to its longitudinal measuring plane at the maximum expected loading.

6.3.4 If there is a torque transducer that measures the torque on the test wheel generated by the braking force, this shall provide output directly proportional to torque with hysteresis less than 1 % of the applied load and nonlinearity up to the maximum expected loading less than 1 % of the applied load. The sensitivity to any cross-axis loading shall be less than 1 % of the applied load. Torque transducer measurements include rolling tire/wheel inertial effects, which shall be compensated for at all test speeds.

6.3.5 If the load force is measured, the accuracy of the measurement shall conform to the requirements set out in 6.3.3. If the load force is assumed constant, it shall be possible to show that the assumed dynamic wheel load is within ±2 % of the actual dynamic wheel load.

6.3.6 Distance shall be measured with a resolution of 0.1 % and an accuracy of ±0.5 % and shall be continuously recorded.

6.3.7 Speed shall be measured with a resolution of 2 kmh [1 mph] and an accuracy of ±1 kmh [±0.5 mph]. It is recommended that these measurements be continuously recorded.

6.4 *Braking Slip:*

6.4.1 The test apparatus shall be such that the chosen fixed braking slip can be maintained within ±3 % of full scale throughout the length of the test surface at the chosen test speed (for example, if the chosen fixed braking slip is 15 %, a braking slip between 12 and 18 % shall be maintained).

6.5 *Test Speed*—With the test tire operating at the chosen fixed braking slip, the test apparatus shall be capable of maintaining the chosen test speed within ±3 % for the duration of the survey.

6.6 *Test Tire*—The test tire shall conform to the applicable ASTM, ISO, or BSI specification or equivalent. Applicable ASTM standards include Specifications E501, E524, E1551 and E1844.

6.7 *Water Application System:*

6.7.1 Water shall be applied to the test surface just ahead of the test tire so as to provide the chosen nominal water film thickness across the full width of the test tire at any test speed.

6.7.2 The water application system shall be protected from the effects of side winds, either by use of a flexible nozzle very close to the test surface or by shielding the nozzle in some way or by using a jet of water with horizontal speed equal and opposite to the test speed and applied slightly wider than the width of the test tire tread.

6.7.3 Water used for testing shall be reasonably clean and have no chemicals such as wetting agents or detergents added and shall not be above 30°C [86°F].

6.7.4 The nominal water film thickness shall be in accordance with the manufacturer's handbook and the test application.

6.7.5 Rate of water flow shall be continuously measured and it is recommended that it be continuously recorded.

6.7.6 Regulation of rate of water flow shall be within ±10 %.

6.8 *Signal-Conditioning and Recording Systems:*

6.8.1 All signal-conditioning and recording equipment shall provide linear output and allow data reading resolution to meet the requirements of 6.3. All systems except the smoothing filter described in 6.8.3 shall provide a minimum bandwidth of at least 0 to 20 Hz (flat within ±1 %).

6.8.2 Measurements shall be recorded in phase and all force signals shall be referenced to a common time base and be passed through the same filter.

6.8.3 A low-pass electronic filter, typically between 4.8 Hz/-3db/4 pole and a 10 Hz/-3db/8 pole, shall be installed in the signal-conditioning circuit.

6.8.4 The static signal-to-noise ratio shall be at least 100 to 1 at full scale on all recording channels.

7. Hazards

7.1 The test apparatus shall comply with all applicable laws and regulations, and all necessary precautions shall be taken to ensure maximum safety of operating personnel and other traffic. No test that involves surface wetting shall be made when the pavement temperature is below 2°C [35°F] and there is a consequent danger that water may freeze on the pavement.

8. Preparation of Apparatus

8.1 Field calibration is carried out according to the manufacturer's handbook.

8.2 Test speed and rate of water flow is chosen according to the test site and the manufacturer's handbook.

8.3 Particular attention shall be paid to the condition of the test tire.

8.3.1 A new test tire shall not be used until it has been conditioned by running at fixed slip at the normal tire inflation pressure to obtain a smooth, uniform rubber tread surface free of any curing agents. For tires not conditioned and tested by the supplier, conditioning may typically be carried out by the operator running the tire dry for about 30 m [100 ft] followed by about 300 m [1000 ft] on a wet surface. The operator shall be aware that these lengths are typical and, on an aggressive surface, the tire shall not be run dry for as much as 30 m and, on a smooth surface, longer conditioning will be required.

8.3.2 A test tire exhibiting damage, flat spots, and other irregularities that may affect test results shall not be used.

8.3.3 A test tire worn to the extent that it is unlikely to complete the test (or series of tests) shall not be used. Criteria for determining wear on the measuring tire are given in the appropriate tire standards (see Specifications E501, E524, E1551 and E1844) and the appropriate manufacturer's handbooks.

8.3.4 For all test tires, the appropriate tire standards (see Specifications E501, E524, E1551 and E1844) provide storage limitations and guidance. If these requirements have not been observed, the tire shall not be used.

8.3.5 Just before each series of tests, the test tire shall be brought to operational readiness by running the test apparatus in test mode and test conditions according to the manufacturer's handbook. The test tire inflation pressure shall then be set to the required value.

9. Calibration

9.1 Field calibration of the force transducers or torque transducers or both is carried out before each test. The calibration signal shall be at least 50 % of the normal vertical load, and the calibration process shall be such that the effects of cross-axle loading or torque loading shall be less than 1 % of the applied load.

9.2 Certifying calibration is performed once per year on a regular basis and also after any major repair to the equipment.

9.3 Calibration of the distance- and speed-measuring systems is carried out to meet the requirements set out in 6.3.6 and 6.3.7.

10. Procedure

10.1 The start point for the test, both longitudinal and lateral, is clearly established at the test site.

10.2 A run-in is established of sufficient length to allow the chosen test speed and rate of water flow (in the case of routine testing) to be achieved before the start point.

10.3 If there is the possibility of a delay between completing the process described in 8.3.5 and starting the test, the run-in is also long enough to bring the test tire back to its stable test condition.

11. Faulty Tests

11.1 Tests that are faulty shall be treated as outliers in accordance with Practice E178. Reasons for identifying a test as faulty include:

11.1.1 Incorrect test speed;

11.1.2 Incorrect rate of water flow;

11.1.3 Incorrect start or finish point;

11.1.4 Incorrect track (normally defined by distance from the center line of the runway or road);

11.1.5 Test tire not having been brought to operational readiness before the start of the test (see 8.3.5);

11.1.6 Test tire tread exceeds wear limits at end of test run;

11.1.7 Incorrect test tire inflation pressure;

11.1.8 Inappropriate surface conditions (for example, buildup of water from previous routine tests); and

11.1.9 Anomalous test values.

12. Test Data

12.1 Measurements made with a CFME have little value without supporting data. This supporting data may be manually collected by the operator or automatically collected and written to the computer file.

12.2 Essential supporting data includes:

12.2.1 Sufficient locational referencing for the test to be repeated if required and for friction data collected to be analyzed in conjunction with other locationally referenced data. Test site, lateral position (such as distance from center line) of the track tested by the CFME, and longitudinal position of each friction length are required;

12.2.2 CFME type and serial number;

12.2.3 Test speed, intended and actual (it is recommended that the actual test speed be recorded for each friction length);

12.2.4 Rate of water flow, intended and actual (it is recommended that the actual rate of water flow be recorded for each friction length). If operational testing is being carried out, rate of water flow will be zero;

12.2.5 Surface condition prior to the test;

12.2.6 Date of test; and

12.2.7 Tire type, serial number, and inflation pressure.

12.3 Nonessential but recommended supporting data include:

12.3.1 Surface temperature, test tire temperature, and ambient temperature;

12.3.2 Weather conditions;

12.3.3 Time of start of test;

12.3.4 Operator; and

12.3.5 Test surface type(s).

13. Report

13.1 The test report shall include all the items listed in 12.2 and it is recommended that it also include the items listed in 12.3.

14. Precision and Bias

14.1 *Precision*—The measurements made in this test method are of the frictional force between a test tire operating at a selected slip and a test surface. Many parameters may cause this frictional force to vary and, consequently, measurements obtained using different types of CFME, or at different test speeds, or with different amounts of water (or other contamination) will not necessarily agree with each other.

14.2 *Bias*—There are no standards or references with which the results of this test can be compared.

15. Keywords

15.1 braking slip friction; braking slip ratio; fixed slip; operational friction testing; routine friction testing

APPENDIX

(Nonmandatory Information)

X1. TEST PROCEDURES

X1.1 CFMEs are used to measure skid resistance on a wide variety of surfaces in a wide variety of circumstances. Consequently, there are many different test procedures governing their use (see Test Method F408).

X1.2 *Airports*:

X1.2.1 Operational testing is carried out to determine whether a winter-contaminated runway is suitable for use (see Test Method F408). It usually consists of two runs, one on either side of the runway centerline, the distance from the centerline being determined by the width of undercarriage of the largest aircraft using the runway. The standard test speed is typically 65 kmh [40 mph].

X1.2.2 Routine testing is carried out to obtain data for scheduling remedial work on the runway surface. A single run on either side of the centerline may be regarded as sufficient or a set of runs covering the whole width of the runway may be preferred. At 3-m [10-ft] spacing, the friction map that can be prepared from a set of runs of this kind provides useful information on rubber buildup and surface polishing. Standard test speeds are typically 65 or 95 kmh [40 or 60 mph] and standard nominal water film thickness is typically 1.00 mm [0.04 in.].

X1.2.3 For all runway testing, it is recommended that the start point for the test shall be as near the runway start as is consistent with the need to achieve the chosen test speed, chosen rate of water flow, and stable condition of the test tire, and that the finish point for the test shall be as near the runway end as is consistent with safe deceleration.

X1.3 *Roads*:

X1.3.1 Operational testing is not often carried out on roads.

X1.3.2 Routine testing is usually carried out on the left wheel track of each lane. The length of the test may be as little as 100 m [300 ft] or as much as 50 km [30 miles]. Standard test speeds as low as 20 kmh [12 mph] and as high as 80 kmh [50 mph] have been established for particular types of CFME and particular applications. Standard nominal water film thicknesses are typically 0.25, 0.50, and 1.00 mm [0.01, 0.02, and 0.04 in.] according to the type of CFME and the application.

X1.4 *Other*:

X1.4.1 On footways and helidecks where the CFME is manually pushed, a standard test speed of 5 kmh [3 mph] has been established. Standard nominal water film thicknesses are typically 1.0 and 0.5 mm [0.04 and 0.02 in.].

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