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Standard Test Method for Determining Longitudinal Peak Braking Coefficient of Paved Surfaces Using Standard Reference Test Tire[1]

This standard is issued under the fixed designation E1337; 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 peak braking coefficient of paved surfaces using a standard reference test tire (SRTT) as described in Specification E1136 that represents current technology passenger car radial tires. General test procedures and limitations are presented for determining peak braking coefficient independent of surface conditions. Actual surface test conditions are determined and controlled by the user at the time of test. Test and surface condition documentation procedures and details are specified. This measurement quantifies the peak braking coefficient at the time of test and does not necessarily represent a maximum or fixed value.

1.2 This test method utilizes a measurement representing the peak braking force on a braked test tire passing over a road surface. This test is conducted with a tire under a nominal vertical load at a constant speed while its major plane is parallel to its direction of motion and perpendicular to the pavement.

1.3 The measured peak braking coefficient obtained with the equipment and procedures stated herein may not necessarily agree or correlate directly with those obtained by other surface coefficient measuring methods.

1.4 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.5 *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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E274 Test Method for Skid Resistance of Paved Surfaces Using a Full-Scale Tire

E556 Test Method for Calibrating a Wheel Force or Torque Transducer Using a Calibration Platform (User Level)

E867 Terminology Relating to Vehicle-Pavement Systems

E1136 Specification for P195/75R14 Radial Standard Reference Test Tire

F377 Practice for Calibration of Braking/Tractive Measuring Devices for Testing Tires[3]

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 *Definitions:*

3.1.1 *chirp test*—the progressive application of brake torque required to produce the maximum value of longitudinal braking force that will occur prior to wheel lockup, with subsequent brake release to prevent any wheel lockup (tire slide).

3.1.2 For other definitions pertaining to this standard, see Terminology E867 and Method F408.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *braking force coefficient, tire*—the ratio of braking force to vertical load.

3.2.2 *braking force coefficient, tire, peak*— the maximum value, as defined in 12.2, of tire braking force coefficient that occurs prior to wheel lockup as the braking torque is progressively increased.

3.2.3 *braking force coefficient, tire, slide*— the value of the braking force coefficient obtained on a locked wheel.

3.2.4 *braking force, tire*—the negative longitudinal force resulting from braking torque application.

[1] This test method is under the jurisdiction of ASTM Committee E17 on Vehicle - Pavement Systems and is the direct responsibility of Subcommittee E17.21 on Field Methods for Measuring Tire Pavement Friction.

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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] Withdrawn.

3.2.5 *braking torque*—the negatively directed wheel torque.

3.2.6 *longitudinal force, tire (F_x)*— the component of a tire force vector in the *X*` direction.

3.2.7 *tire-axis system*—the origin of the tire-axis system is the center of the tire contact. The *X*` axis is the intersection of the wheel plane and the road plane with a positive direction forward. The Z` axis is perpendicular to the road plane with a positive direction downward. The Y` axis is in the road plane, its direction being chosen to make the axis system orthogonal and right-hand (see Fig. 1 in Method F408).

3.2.8 *tire forces*—the external forces acting on the tire by the road.

3.2.9 *torque wheel (T)*—The external torque applied to a tire from a vehicle about the wheel spin axis. Driving torque is positive wheel torque; braking torque is negative wheel torque.

3.2.10 *vertical load (F_z)*—the downward vertical component of force between the tire and the road.

4. Summary of Test Method

4.1 The measurements are conducted with a standard reference test tire (Specification E1136) mounted on a test trailer towed by a vehicle. The trailer contains a transducer, instrumentation, and actuation controls for the braking of the test tire. See 6.6 for trailer instrumentation.

4.2 The test apparatus is normally brought to a test speed of 40 mph (64 km/h). The brake is progressively applied until sufficient braking torque results to produce the maximum braking force that will occur prior to wheel lockup. Longitudinal force, vertical load, and vehicle speed are recorded with the aid of suitable instrumentation and data acquisition equipment.

4.3 The peak braking coefficient of the road surface is determined from the ratio of the maximum value of braking force to the simultaneous vertical load occurring prior to wheel lockup as the braking torque is progressively increased.

5. Significance and Use

5.1 Pavement surfaces have different traction characteristics, depending on many factors. Surface texture, binder content, usage, environmental exposure, and surface conditions (that is, wet, dry) are some of the factors.

5.2 The measured values represent peak braking coefficients for tires of the general type in operation on passenger vehicles, obtained with a towed test trailer on a prescribed road surface, under user defined surface conditions. Such surface conditions may include the water depth used to wet the road surface and the type of water application method. Variations in these conditions may influence the test results.

6. Apparatus

6.1 The apparatus consists of a tow vehicle and test trailer. The vehicle and trailer must comply with all legal requirements applicable to state laws when operated on public roads.

6.2 *Tow Vehicle*—The vehicle shall have the capability of maintaining a test speed of 40 mph (64 km/h) within ±0.5 mph (±0.8 km/h) even at maximum level of application of braking forces.

6.3 *Test Trailer*—The test wheel shall be equipped with a sufficient braking torque to produce the maximum value of braking test wheel longitudinal force at the conditions specified.

6.3.1 Each of the trailer wheels shall have a suspension capable of holding toe and camber changes to within ±0.05° with maximum vertical suspension displacements under both static and dynamic conditions.

6.3.2 The rate of brake application shall be sufficient to control the time interval between initial brake application and peak longitudinal force to be between 0.3 and 0.5 s.

6.4 *Vertical Load*—The trailer shall be of such a design as to provide a static load of 1031 ± 15 lbf (4586 ± 67 N) to the test wheel and on detachable trailers a static down load of 100 to 200 lbf (445 to 890 N) at the hitch point.

6.5 *Tire and Rim*—The test tire shall be the standard reference test tire (SRTT) for pavement tests, as specified in Specification E1136, mounted on a suitable 14 by 6-in. rim.

6.5.1 When irregular wear or damage results from tests, or when wear or usage influences the test results, the use of the tire should be discontinued.

6.6 *Instrumentation:*

6.6.1 *General Requirements for Measuring System*—The instrumentation system shall conform to the following overall requirements at ambient temperatures between 40 and 100°F (4 and 38°C):

6.6.1.1 Overall system accuracy of ±1.5 % of applied load from 200 lbf (890 N) to full scale; for example, at 200 lbf (890 N), applied calibration force of the system output shall be determinable within ±3 lbf (±13 N).

6.6.1.2 The exposed portions of the system shall tolerate 100 % relative humidity (rain or spray) and all other adverse conditions, such as dust, shock, and vibrations which may be encountered in highway operations.

6.6.1.3 *Braking Forces*—The braking force measuring transducer shall measure longitudinal reaction force within a range between 0 and 2000 lbf (0 and 8.9 kN) generated at the tire-pavement interface as a result of brake application. The tire force-measuring transducer shall be of such design as to measure the tire-pavement interface force with minimum inertial effects. Transducers are recommended to provide an output directly proportional to force with hysteresis less than 1 % of the applied load, nonlinearity less than 1 % of the applied load up to the maximum expected loading, and sensitivity to any expected cross-axis loading or torque loading less than 1 % of the applied load. The force transducer shall be mounted in such a manner as to experience less than 1° angular rotation with respect to its measuring plane at the maximum expected loading.

6.6.1.4 *Vertical Load*—The vertical load measuring transducer shall measure the vertical load at the test wheel during brake application. The transducer shall have the same specifications as those described in 6.6.1.3.

NOTE 1—Other transducer systems may be used to determine peak braking coefficients if they can be shown to correlate with the force-measuring transducer system with the same overall accuracy.

6.6.1.5 *Vehicle Speed-Measuring Transducers*—Transducers such as "fifth wheel" or a free-rolling wheel coupled tachometer shall provide speed resolution and accuracy of ±1.5 % of the indicated speed or ±0.5 mph (±0.8 km/h), whichever is greater. Output shall be directly viewable by the driver and shall be simultaneously recorded. Fifth wheel systems shall conform to Method F457.

6.6.1.6 *Signal Conditioning and Data Acquisition*—All signal conditioning and recording equipment shall provide linear output and shall allow data reading resolution to meet the requirements of 6.6.1.1.

6.6.1.7 All strain-gage transducers shall be equipped with resistance shunt calibration resistors or equivalent that can be connected before or after test sequences. The calibration signal shall be at least 50 % of the normal vertical load and shall be recorded.

6.6.1.8 A digital data acquisition system shall be employed to individually digitize the braking force, vertical load, and vehicle speed analog outputs. The braking force, vertical load, and test wheel speed input signals to be digitized shall be sampled (as close to simultaneous as possible to minimize phase shifting) at 100 samples per second for each channel from unfiltered analog signals. Vehicle speed can be analog filtered, if necessary, to remove noise since this is a steady-state signal.

NOTE 2—Experience indicates that data sampling at 100 samples per second of unfiltered analog skid trailer data will properly describe the significant frequencies. To prevent "aliasing," caution must be exercised in digitizing skid trailer data which contains any significant frequencies above 50 Hz or other types of analog data.

7. Hazards

7.1 The test vehicle, as well as all attachments to it, shall comply with all applicable state and federal laws. All necessary precautions shall be taken beyond those imposed by laws and regulations to ensure maximum safety of operating personnel and other traffic. No test shall be made when there is danger that dispersed water may freeze on the pavement.

8. Preparation of Apparatus

8.1 *Preparation of Test Tire:*

8.1.1 Trim the test tires to remove all protuberances in the tread area caused by mold air vents or flashes at mold junctions.

8.1.2 Test tires should be stored in such a location that they all have the same ambient temperature prior to testing and shield them from the sun to avoid excessive heating by solar radiation.

8.1.3 Mount the test tire on Tire and Rim Association (TRA) recommended rim[4] (6.5) by using conventional mounting methods. **Caution:** Assure proper bead seating by the use of a suitable lubricant. Excessive use of lubricant should be avoided to prevent slipping of the tire on the wheel rim.

8.1.4 Check the test tires for the specified inflation pressure at ambient temperature (cold), just prior to testing. The test tire inflation pressure shall be 35 ± 0.5 psi. (241 ± 3 kPa)

[4] Current recommendations available from the Tire and Rim Association, 3200 Market St., Akron, OH 44313.

9. Calibration

9.1 *Vehicle 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 of a length appropriate for the method of timing. Load the test trailer to its specified operating weight for this calibration. Record speed variations during a traverse with the test system. Make a minimum of three runs at each test speed to complete the calibration. Other methods of equivalent accuracy may be used. Calibration of a fifth wheel shall be performed in accordance with Method F457.

10. Conditioning

10.1 *Pretest Tire Conditioning:*

10.1.1 Test tire pretest conditioning shall be performed to precondition all tires prior to initial testing. Pretest conditioning is to be done only once per tire and prior to any actual test measurements. This process is recommended because the new tire burnish effect may have an influence on the peak braking coefficient obtained and to minimize test variability caused by transient, non-preconditioned, tire braking performance.

10.1.2 Pretest tire conditioning shall be conducted on a dry and level surface. Each tire shall be chirped ten times at 20 mph (32 km/h) under test load.

10.2 *General Test Conditions:*

10.2.1 The test surface shall be free of loose material or foreign deposits.

10.2.2 Do not test when wind conditions interfere with wetted test repeatability. Test results may be influenced by wind speed, or direction, or both. The magnitude of this dependence is a function of the water depth, application procedures, and surface wind protection.

11. Procedure

11.1 Warm up electronic test equipment as required for stabilization.

11.2 Install an SRTT (Specification E1136) in the test position of the test trailer. A tire with a similar loaded radius and high cornering properties should be used on the opposite side to level the axle and to minimize trailer yaw during brake torque applications.

11.3 Check and, if necessary, adjust the test trailer static weight on the test tire to the specified test load (see 6.4).

11.4 Check and adjust tire inflation pressure as required immediately before testing to specified value (see 8.1.4).

11.5 When testing on an externally wetted test surface, offset the trailer test wheel sufficiently to prevent "tracking" of the towing vehicle. Twelve to sixteen in. (305 to 406 mm) is suggested.

11.6 Record tire identification and other data, including date, time, ambient temperature, test surface temperature, tire durometer, test surface type, and water depth (if wetted surface is used). Measure the water depth with a variable height probe type device.

11.7 Record electrical calibration signals prior to and after testing each surface, or as needed to ensure valid data.

11.8 Perform pretest tire conditioning (10.1) if using a new tire.

11.9 Conduct test at the required test vehicle speed. It is recommended that peak braking coefficient measurement tests be conducted using the chirp test methodology to minimize tire damage due to tire sliding.

11.10 Make at least eight determinations of the peak braking coefficient evenly distributed over the test surface with the test system at the specified test speed.

11.11 *Lateral Positioning of Test Vehicle on Highway Surfaces*—Normally, testing shall be done in the center of either wheel track of a traffic lane on a highway. The specific details regarding lane and the wheel-path used should be provided when reporting the data.

11.12 *Test Speeds:*

11.12.1 The standard test speed shall be 40 mph (64 km/h), and tests shall normally be conducted at that speed. Where the legal maximum speed is less than 40 mph (64 km/h), the tests may have to be conducted at a lower speed. Where the legal speed is considerably in excess of 40 mph (64 km/h), tests may be made at the prevailing traffic speed, but it is recommended that at the same locations, additional tests be made at 40 mph (64 km/h). Maintain test speeds within ±1 mph (1.5 km/h).

11.12.2 The test speed must be given when the peak braking coefficient is quoted. This may be done by adding the numerals of the actual test speed in miles per hour in parentheses to the coefficient, for example, 0.50(50) indicates the peak braking coefficient was obtained at a test speed of 50 mph (80 km/h).

12. Calculation

12.1 *Data Reduction:*

12.1.1 Digitally filter the digitized input analog signals of braking force, vertical load, and vehicle speed using a five point moving average technique.

12.1.2 *Digital Filtering Methodology*—Calculate an average value for the first five digital data points. Drop the first data point and add the sixth data point, calculate another five point average value. Repeat this procedure for all remaining data points. This sequence is done individually on all the above digitized input analog signals. The following example computations illustrate the method using one channel.

$$(pt1 + pt2 + pt3 + pt4 + pt5)/5 = PT1$$
$$(pt2 + pt3 + pt4 + pt5 + pt6)/5 = PT2$$
$$(pt3 + pt4 + pt5 + pt6 + pt7)/5 = PT3$$

A new set of data points (indicated by capital letters) are then defined to represent the filtered data for each channel (that is, Avg ptx = PTy).

PT1, PT2, PT3, etc. – braking force
PT1, PT2, PT3, etc. – vertical force

12.2 Determining and Calculating Peak Braking Coefficient.

12.2.1 The peak braking coefficient shall be determined for each run (brake application).

12.2.2 Using the digitally filtered data (PT1, PT2, PT3, etc.), scan the longitudinal channel and determine the highest absolute filtered value (PTy) prior to wheel lock up. Calculate an average peak braking force value using the highest filtered value (PTy) and one filtered point directly before (PTy_{-1}) and directly after it (PTy_{+1}). This three point average is the peak braking force value developed for this individual lock up.

12.2.3 Determine the vertical load value from its respective digitally filtered data that corresponds to the highest absolute value for braking force, from 12.2.2. Calculate an average vertical load value using this corresponding value and one point directly before and directly after it. This three point average is the vertical load value that corresponds to the average peak braking force for this individual lock up.

12.2.4 Calculate the peak braking coefficient by dividing the three point average peak braking force, determined from 12.2.2, by the three point average vertical load, as determined in 12.2.3. The peak braking coefficient should be reported to two (2) decimal places.

12.3 For each test (11.10) the mean and standard deviation for peak braking coefficient are calculated from the individual determinations.

13. Report

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

13.1.1 Identify test procedure used,
13.1.2 Location and identification of test section,
13.1.3 Date and time of day,
13.1.4 Weather conditions,
13.1.5 Lane and wheel-path tested,
13.1.6 Speed of test vehicle (for each test),
13.1.7 Peak braking coefficient (for each test),
13.1.8 Water depth, if wetted surface is used, and
13.1.9 Ambient and surface temperature.

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

13.2.1 Location and identification of test section,
13.2.2 Number of lanes and presence of lane separators,
13.2.3 Grade and alignment,
13.2.4 Pavement type, mix design of surface course, condition, and aggregate type (specific source, if available),
13.2.5 Age of pavement,
13.2.6 Average daily traffic,
13.2.7 Posted speed limit,
13.2.8 Date and time of day,
13.2.9 Weather conditions,
13.2.10 Lane and wheel-path tested,
13.2.11 Ambient and surface temperature, and
13.2.12 Average, high, and low peak braking coefficient for the test section and speed at which the tests were made. (If values are reported that were not used in computing the average, this fact should be reported.)

14. Precision and Bias

14.1 *Precision*—Data are not yet available for making a statement on the precision of this test method. When such data become available, a precision statement will be included in this test method.

14.2 *Bias*—There are no standards or references with which the results of this test can be compared. The function of the test as indicated above is to be able to make comparisons among road surfaces tested with the same tire. It is believed that the results of the test method are adequate for making such comparisons without an external reference for assessing accuracy. It must be noted that surface friction is affected by many variables such as environmental conditions, usage, age, surface contamination (externally applied water), etc., and measured values are only valid until one of these conditions significantly changes.

15. Recommendations for Tire Use and Operational Requirements

15.1 When irregular wear or damage results from tests, or when wear or usage influences the test results, the use of the tire should be discontinued.

NOTE 3—Test results such as measured braking force may be influenced by tire groove depth or tread hardness, or both. The magnitude of this dependence is a function of the water depth, pavement characteristics, test speed, tire aging effects, and break-in (preconditioning).