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Standard Test Method for Determining the Stopping Distance Number by Initial Speed and Stopping Distance at Traffic Incident Sites[1]

This standard is issued under the fixed designation E2341/E2341M; 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 determination of an average stopping distance number (SDN) under the conditions that this method was executed. The experimental conditions are generally intended to be similar to those of a specified traffic incident. The data from this method is not comparable to measured distances of a specified traffic incident vehicle that cannot be shown to have continuous, full application of its braking system.

1.2 This test method determines the SDN from the measured stopping distance and initial speed when the wheels on specified axles are braked in the same manner as the specified traffic incident vehicle. The evaluation vehicle's braking system is required to duplicate the specified incident vehicle for both type (conventional, partial ABS, or full ABS) and functionality (all brakes functional or not).

1.3 The method documents the test conditions as a basis for evaluating their similarity to conditions of a specified traffic incident.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the test, 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.

1.5 *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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E178 Practice for Dealing With Outlying Observations

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

F403 Test Method for Tires for Wet Traction in Straight-Ahead Braking, Using Highway Vehicles (Withdrawn 2007)[3]

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

3. Summary of Test Method

3.1 The test apparatus consists of a vehicle and tires similar to the traffic incident vehicle and instruments to measure and record initial speed and stopping distance. If the incident vehicle did not have ABS and the test vehicle does, the ABS must be disabled.

3.2 The test is performed on the roadway where the traffic incident occurred with surface conditions similar to those that existed at the time of the traffic incident.

3.3 The test vehicle is brought above the desired test speed and permitted to coast onto the test section. The brakes are then very quickly and forcefully applied to cause immediate lock-up of all desired wheels and to skid to a stop (note: if the car is equipped with ABS, lock-up will not be obtained). In either case the initial speed at brake application, the stopping distance, and tire mark lengths are recorded. If tire marks do not vary smoothly in darkness, width or density, the variation in appearance needs to be described.

3.4 The deceleration of the roadway/vehicle combination, called the stopping distance number (SDN), is determined from

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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] The last approved version of this historical standard is referenced on www.astm.org.

the measured stopping distance and the initial speed. SDN differs from skid resistance since it includes other factors such as grade, air resistance, and rolling resistance, especially for non-locked wheels.

NOTE 1—Since speed has a significant effect on pavement surface skid resistance measurements, the SDN can be expected to be considerably different at higher speeds from that at lower speeds as well. Generally, the SDN can be expected to decrease with increasing speed.

4. Significance and Use

4.1 The SDN determined by this method represents an average over the interval from the beginning of brake application to the rest position. It may be a reasonable estimate of the SDN during one or more portions of the specified traffic incident if the test conditions and the incident conditions are sufficiently similar. Since this standard determines an average SDN from the initial speed to rest, care should be exercised in any application of the test results to a portion of the incident that does not end with the specified traffic incident vehicle at rest.

4.2 The uncertainty of the SDN determined by this method can be evaluated by procedures shown in this method. The relationship between the SDN of this test method and the SDN of a specified traffic incident is beyond the scope of this method. The similarity between test and specified traffic incident SDN's depends on the similarity of vehicles, vehicle ballast conditions, vehicle weight transfer during braking, vehicle tires, pavement surface, pavement surface contamination, and vehicle speed during a particular phase of the incident sequence.

4.3 The SDN determined by this method does not necessarily agree or correlate directly with other methods of skid resistance measurements, such as Test Method E274. This test method is suitable for those situations where adequate similarity can be shown.

4.4 When it is known that a particular wheel brake was not functional during the incident, the method provides for only the desired wheels to be braked on the test vehicle to duplicate the specified traffic incident vehicle.

5. Test Equipment

5.1 *Test Vehicle*—The evaluation vehicle that is intended to duplicate the performance characteristics of the specified traffic incident vehicle. The test vehicle should be similar to the incident vehicle because the test vehicle's performance characteristics cannot be removed from the SDN and will be different than the specified traffic incident vehicle. The traffic incident vehicle should be used, however, this is often not practical. Therefore, the test vehicle must be as close to the same year, make, and model, and be equipped with the same options as possible.

5.1.1 *Weight and Weight Distribution*—The load the vehicle places on each of its supporting tires while the vehicle is at rest. The total vehicle weight should be similar to that of the incident vehicle. The static weight distribution should be similar to the incident vehicle. The height of the center of mass, the wheelbase, and the inertial mass should be similar to those of the traffic incident vehicle.

5.1.2 *Braking System*—The test vehicle brakes should be similar to those of the incident vehicle, that is, drum, disk, ABS, and so forth. If the brake system is not ABS, the driver and brake system must be capable of locking all desired wheels during a stop.

5.1.3 *Tires*—Test tires must be similar to those in the specified traffic incident. Tires, depending on their specific performance balance, can vary substantially in their braking performance. Every effort should be made to duplicate the tire on the specified traffic incident vehicle. The test vehicle tires should match by manufacturer, brand name, tire line, tire size and UTQG (Uniform Tire Quality Grade) ratings, construction (bias, radial, and so forth), state of wear and inflation pressures should be as similar as is reasonable. Whenever possible, the tires from the specified traffic incident vehicle should be used on the test vehicle. (Also see Test Method F403.)

5.2 *Instrumentation:*

5.2.1 *Vehicle Initial Speed Measuring Device*—The test vehicle shall be equipped with devices capable of measuring and holding the value of the speed immediately prior to the braking interval. The speed-indicating device shall provide a speed resolution and accuracy of ±1 mph [±1.5 km/h]. An appropriately calibrated vehicle speedometer, an on-board radar gun, or fifth wheel are suitable speed measuring devices. The initial speed memory device must be a suitably calibrated continuous recording device attached to the speed indicating device or an operator who observes the speed display continuously and notes the value at the initiation of braking. The vehicle speedometer does not usually have the required accuracy.

5.2.2 *Distance Measuring Device*—The distance from the initiation of braking to the rest position shall be measured by a device with a fractional uncertainty equal to or less than the fractional uncertainty of the speed measuring device (for example, for 40 ± 1 mph [65 ± 2 km/h] the fractional uncertainty is ±1/40 = ±2.5 % or 1.25 ft in 50 ft [0.5 m in 20 m]). A steel tape or a fifth wheel are suitable devices. If a fifth wheel assembly with speed and distance readouts is used, it should meet the requirements specified in Test Method F457. If a tape is used, then a device similar to the American Automobile Association (AAA) marker must be used to mark the pavement when brake pedal pressure is applied and measurement is made from the mark to the final resting point of the vehicle.

5.2.3 *Initial Braking Event Marker*—A device capable of marking the pavement or initiating a distance counter at the beginning of the braking intervals would be installed on the vehicle. The device may be actuated by the initial motion of the brake pedal, contact force on the brake pedal, or brake system pressure of 25 psi [170 kPa] for fully hydraulic brake systems.

NOTE 2—The time difference between initial pedal motion and the beginning of braking is nominally less than 0.1 s which corresponds to less than 6 ft at 40 mph [1.83 m at 65 km/h].

On airbrake systems, only a pressure switch in the service line shall be used. A gun powder cartridge device similar to an AAA marker is a suitable device for marking the pavement. The actual event used to indicate the beginning of the braking interval shall be reported.

5.2.4 *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, should be installed in the hydraulic brake system or the brake pedal to actuate the stopping-distance counter or mark the pavement if the distance measuring system is not automatic.

6. Calibration

6.1 *Speed*—Calibrate the test vehicle speed indicator at speeds which bound the range intended for the test. Locate two markers on a reasonably straight level roadway that are a measured distance apart (within ±1 % uncertainty). The minimum distance is the distance traveled in 45 s at the calibration speed (about 0.5 mile for 40 mph [0.8 km for 65 km/h]). For two speeds which bound the calibration range and at least two other speeds in the range, operate the vehicle at constant speed through the marked section measuring the travel time between markers (±0.5 s) and speed (±0.5 mph [±0.8 km/h]). If the instantaneous speed varies from the average by more than 1 mph, discard that run. The calibrated speed is determined from a least-squares line fit to the measured and indicated data. Radar guns and other electronic speed measuring devices should be calibrated by the manufacturers recommended method.

6.2 *Distance*—Calibrate the fifth-wheel distance transducers and counters over a measured distance at least 200 ± 1 ft [60.0 ± 0.3 m]. The counter should correctly indicate the measured distance ±0.5 % or the counter results for the SDN test should be corrected for the calibration error, that is, test count time calibration count/calibration distance. Fifth wheels should be calibrated per Test Method F457.

NOTE 3—A steel tape in good condition does not need to be calibrated.

7. Test Site

7.1 *Surface Condition*—The roadway surface should be the same surface present during the specified traffic incident except for normal wear. If the surface during the specified traffic incident was not clean and dry, the material contaminating the surface must be characterized and pavement contamination similar to that during the specified traffic incident applied to the test surface.

NOTE 4—A roadway surface that is wetted and tested after an extended dry period may not exhibit the same SDN after the surface has been thoroughly rain washed.

7.2 *Pavement Wetting*—If the incident surface was wet, the test surface should be wetted to obtain similar water depth or drained conditions. When water is applied artificially, wet the test lane at the test site just prior to SDN 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. Repeated application of water to the test lane between each test as required to maintain similar wetness conditions. If other contaminates were present during the accident, they should be duplicated as closely as possible. If the accident occurred on dry pavement, no wetting is required.

7.3 *Positioning of Test Vehicle on Highway*—Normally, the test should be performed in the same lane/lanes traveled by the specified traffic incident vehicle with the path of travel being the same. Where this is not possible, separate measurements must be made on each section of different frictional properties in the same direction of travel as the incident vehicle.

7.4 *Test Speed*—The standard test speed should be that of the specified traffic incident vehicle. If the speed is not known, a test should be conducted at 30 mph [50 km/h]. From this test, an estimated speed can be calculated and the test should be rerun at the calculated speed. If the specified traffic incident vehicle speed is greater than the speed limit, the speed limit should be used. It should be noted that the SDN measured at the lower speed might be higher and, therefore, gives a higher estimated speed or a longer stopping distance, SD, estimate. At speeds above 40 mph [65 km/h], caution should be used where the site is not clear and straight.

8. Procedure

8.1 When the vehicle, instruments, and test surfaces are ready, drive the vehicle toward the site at a speed slightly above the desired test speed. Allow the vehicle to coast into the test section. When in the test section, very quickly and forcibly apply the brakes to bring the vehicle to a stop. For non-ABS vehicles, station observers or video cameras on both sides of the test section to document the locked wheel condition. Caution should be used when locking all wheels since this can cause the test vehicle to yaw leading to an unsafe condition. If any yaw starts, the brakes should be released immediately.

8.2 Record the following in addition to section 11.5:

8.2.1 The speed when brakes are applied,

8.2.2 The stopping distance,

8.2.3 The wheels that locked, and

8.2.4 The length of skid mark produced by each wheel measuring back from their stopped position. Two lengths should be reported for each mark, the apparent length when viewed from directly above, and the apparent length when viewed at a shallow angle in the direction of travel. If the skid mark does not vary smoothly and monotonically in darkness, width, and density, describe the variation and associated lengths.

8.3 Repeat the procedure for other speeds and paths as desired.

9. Calculation

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

Inch-pound units:

$$SDN = \frac{V^2}{30SD} \tag{1}$$

Metric units:

$$SDN = \frac{V^2}{255SD} \tag{2}$$

where:

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

SD = stopping distance, ft [m].

To handle outliers, see Practice E178.

10. Uncertainty

10.1 The fractional uncertainty of each calculated stopping distance number is:

$$\Delta SDN/SDN = [(2\ \Delta V/V)^2 + (\Delta SD/SD)^2]^{1/2} \quad (3)$$

where:

Δ = uncertainty of subsequent speed calculations using the test SDN will be about half the uncertainty of SDN.

NOTE 5—For the limits in this standard at 40 mph, ΔSDN/SDN will be about 5.6 %. The speed uncertainty, 1/40 corresponding to 2.5 %, is the dominant factor.

10.2 The fractional uncertainty of subsequent speed calculations using the test SDN will be about half the uncertainty of SDN.

10.3 *Incident SDN*—The relationship between the site SDN and the SDN that prevailed during a specified traffic incident must be established by methods that are beyond the scope of this standard.

11. Reports

11.1 *Test Vehicle:*

11.1.1 Brand,

11.1.2 Year,

11.1.3 Model,

11.1.4 Vehicle Identification Number,

11.1.5 Loaded wheel weights,

11.1.6 Brake system type,

11.1.7 Description of the desired braking condition, and

11.1.8 Description of the modifications to the braking system to achieve desired braking conditions.

11.2 *Tires (Side/Axle) L1 L2 L3 R1 R2 R3:*

11.2.1 Brand,

11.2.2 Model,

11.2.3 Size and type,

11.2.4 Size and type recommended by vehicle manufacturer,

11.2.5 Tread design,

11.2.6 Tread depth,

11.2.7 Tire pressure,

11.2.8 Tread width,

11.2.9 Traction code label on tire sidewall, and

11.2.10 DOT Number.

11.3 *Pavement:*

11.3.1 Road number/road name/location/milepost,

11.3.2 Road grade,

11.3.3 Road alignment/superelevation/cross slope,

11.3.4 Number of lanes and presence of lane separators,

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

11.3.6 Speed limit as posted, and

11.3.7 Pavement surface temperature.

11.4 *General Test Conditions:*

11.4.1 Speed indicator type/calibration date/least-squares slope/calibration standard deviation,

11.4.2 Initial speed memory device,

11.4.3 Braking event marker type,

11.4.4 Distance measuring device/calibration date/correction factor,

11.4.5 Date of test,

11.4.6 Operator/instrument observer, and

11.4.7 Other equipment/observers used.

11.5 *Test Run Data:*

11.5.1 Clock time,

11.5.2 Lane/path,

11.5.3 Direction,

11.5.4 Surface condition/treatment,

11.5.5 Roadway contamination or other anomalies,

11.5.6 Initial speed,

11.5.7 Stopping distance—SD,

11.5.8 Tire Mark Length (side/axle) L1 L2 L3 R1 R2 R3:

11.5.8.1 Viewed from above,

11.5.8.2 Shallow view along path, and

11.5.8.3 Wheels locked.

11.5.9 Weather:

11.5.9.1 Ambient temperature,

11.5.9.2 Wind/direction,

11.5.9.3 Precipitation/rate/duration, and

11.5.9.4 Cloud cover/sun/shade.

11.6 *Test Results Summary for Each Test Section:*

11.6.1 Test section/path,

11.6.2 Travel direction,

11.6.3 Number of runs,

11.6.4 SDN and standard deviation of the SDN for the runs,

11.6.5 Any deviations from the procedure (such as a lower test speed) and a note that the SDN obtained is over or underestimated, and

11.6.6 Uncertainty from Section 10.

12. Precision and Bias

12.1 The relationship of observed SDN 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 with ±5 % of the average value. SDN data obtained with the same operator and under identical test conditions should not be considered suspect unless they differ by more than 5 %.

13. Keywords

13.1 stopping distance number