Designation: E2101 – 15

Standard Test Method for Measuring the Frictional Properties of Winter Contaminated Pavement Surfaces Using an Averaging-Type Spot Measuring Decelerometer[1]

This standard is issued under the fixed designation E2101; 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 frictional properties of winter contaminated pavement surfaces using an averaging-type spot measuring decelerometer. If a data phone is used, it should meet all the requirements where the word decelerometer is used in this standard. The method produces a reading that is proportional to the deceleration sustained by a test vehicle fitted with pneumatic rubber tires braking with all wheels locked. A friction index for a section of winter contaminated pavement is determined from the average of several deceleration measurements recorded over the section of winter contaminated pavement.

1.2 This test method is applicable to averaging-type spot measuring decelerometers.

1.3 This test method is applicable to the following winter contaminated pavement surface conditions:

1.3.1 Ice;

1.3.2 Wet ice (ice covered with a thin film of moisture of a depth insufficient to cause hydroplaning);

1.3.3 Compacted snow, any depth;

1.3.4 Slush on ice, slush not exceeding 3 mm (0.1 in.) in depth;

1.3.5 Loose, dry snow, not exceeding 25 mm (1 in.) in depth;

1.3.6 Ice control chemical solution on ice; and

1.3.7 Sand on ice.

1.4 This test method shall not be used when the following winter contaminated pavement surface conditions are present:

1.4.1 Water on a bare pavement surface;

1.4.2 Slush; and

1.4.3 Loose snow exceeding 25 mm (1 in.) in depth.

1.5 The values stated in SI units are to be regarded as the standard. The values in parentheses are in inch-pound units and are not exact equivalents, therefore, each system must be used independent of the other, without combining values in any way.

1.6 *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]

E867 Terminology Relating to Vehicle-Pavement Systems

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms, refer to Terminology E867.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *averaging-type spot measuring decelerometer, n*—a spot measuring decelerometer that measures the average rate of deceleration of a test vehicle during braking.

3.2.2 *g*—a unit of acceleration where 1 g is equal to the acceleration of gravity, 9.8 m/s^2 (32.2 ft/s^2).

3.2.3 *spot measuring decelerometer, n*—a device used to measure vehicle deceleration on roads and runway surfaces.

4. Summary of Test Method

4.1 A spot measuring decelerometer is placed in a test vehicle so that the decelerometer can measure the deceleration of the vehicle during braking.

4.2 The test vehicle is accelerated over a section of winter contaminated pavement and the brakes are applied firmly to cause all the wheels to lock.

4.3 The friction coefficient developed between the pavement surface and the vehicle is directly related to the deceleration of the vehicle recorded by the decelerometer when the deceleration is reported in g units.

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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.

5. Significance and Use

5.1 Knowledge of the frictional properties of a winter contaminated pavement surface is essential to evaluate the braking effort of ground vehicles or aircraft operating on a pavement surface. The presence of contaminants on a pavement surface will affect the frictional properties of the surface in a manner which is difficult to evaluate by visual observation alone. The frictional properties of a winter contaminated pavement surface can be characterized using a spot measuring decelerometer which provides a measurement of the surface friction and assists with the evaluation of pavement winter maintenance requirements.

5.2 The measurements produced by this test method should not be used as the sole criteria to determine pavement winter maintenance requirements. The measurements would normally be combined with visual and other observations to provide a more complete analysis of the pavement surface conditions. A certain amount of discretion is required on the part of the operator as this test method provides only a "spot" measurement of the surface condition. The objective of the operator is to identify areas of the winter contaminated pavement surface which may have lower friction and then obtain friction measurements in those areas. This makes the test method somewhat conservative by nature in comparison to the actual friction potential.

5.3 The measurements produced by this test method are dependent on the test vehicle parameters and on the braking technique of the vehicle operator.

6. Apparatus

6.1 *Any Spot Measuring Decelerometer,* electronic or mechanical, having the following features:

6.1.1 Capable of measuring the deceleration of a vehicle to an accuracy of within ± 0.02 g, including linearity and hysteresis;

6.1.2 Capable of indicating the average deceleration rate of a vehicle during braking;

6.1.3 Capable of low-pass filtering of the deceleration signal to attenuate disturbances emanating from a vehicle engine, vehicle driveline, tire vibrations, and noise or other spurious signals that may interfere with obtaining the deceleration of the vehicle with respect to ground; and

6.1.4 Capable of operating inside a vehicle.

6.2 *Any Vehicle,* having the following features:

6.2.1 *Vehicle Type*—An intermediate or full size automobile of the sedan or station wagon body type, or a truck intended for utility or passenger/cargo use, with a vehicle mass between 1000 and 2000 kg (2200 and 4400 lb). The vehicle can be either front wheel, rear wheel, or four wheel drive.

6.2.2 *Brake System*—Preferably, the brake system shall be capable of locking all of the vehicle wheels upon a gradual but firm application of force on the brake pedal. Alternatively, the brake system shall be capable of locking the two front vehicle wheels upon a gradual but firm application of force on the brake pedal (as in the case of a vehicle featuring a rear-wheel Anti-lock Brake System [ABS]). Vehicles equipped with a four-wheel ABS are not acceptable unless there is a method of disabling the four-wheel ABS when taking friction measurements.

6.2.3 *Shock Absorbers*—Shock absorbers shall be of the "heavy-duty" type.

6.2.4 *Tires*—All tires on the vehicle shall be of the same type construction, be of a size and type approved by the manufacturer of the vehicle for use on that vehicle, and shall show similar tread wear not exceeding 75 % of the original tread depth. Tires mounted to the same axle shall be of the same tread configuration.

6.2.5 *Traction Aids*—Tires shall be free of traction aids such as metallic studs, embedded grit, snow chains, etc.

6.2.6 *Weight Distribution*—Axle loading shall be between 48/52 front-to-rear and 60/40 front-to-rear. Ballasts may be used to achieve the proper weight distribution.

7. Hazards

7.1 The hazards encountered when carrying out this test method are mainly the hazards normally associated with the operation of a vehicle on winter contaminated surfaces. It is the vehicle operator's responsibility to evaluate the quality of the surface and operate the test vehicle in a suitable manner so as to prevent injury or damage to personnel and equipment.

7.2 *Loss of Directional Control*—A loss of vehicle directional control will result when the front wheels are locked during the braking portion of the test. It is the vehicle operator's responsibility to ensure the vehicle is headed in the correct direction prior to applying the brakes. Under most circumstances, releasing the force applied to the brake pedal will return directional control of the vehicle to the operator. If this method is used on a highway, even more caution is needed because of the narrow pavement.

7.3 *Vehicle Instability*—Locking the rear wheels will place the vehicle in an unstable condition which may cause the vehicle to rotate "end-to-end". It is the vehicle operator's responsibility to ensure the vehicle is headed in the correct direction prior to applying the brakes. Under most circumstances, releasing the force applied to the brake pedal will return stability to the vehicle.

7.4 *Visibility*—It is the vehicle operator's responsibility to ensure that visibility is sufficient to reveal any obstacles that may lay in the path of the vehicle prior to applying the brakes. The loss of directional control associated with locking the front wheels may make it difficult or impossible to avoid obstacles once braking has started.

8. Preparation of Apparatus

8.1 *Spot Measuring Decelerometer:*

8.1.1 *Installation*—The spot measuring decelerometer shall be installed in the vehicle in accordance with the installation instructions provided with the decelerometer.

8.1.2 *Positioning and Securement*—The spot measuring decelerometer shall be positioned on a horizontal surface, in the directional axis of travel, and secured to prevent any displacement during testing. The spot measuring decelerometer shall

not be placed on a seat or cushioned surface. The display and controls of the spot measuring decelerometer shall be accessible to the operator.

8.2 *Vehicle:*

8.2.1 *Tires*—Tires shall be inflated to the vehicle manufacturer's recommended pressure.

8.2.2 *Shock Absorbers*—Shock absorbers shall be in serviceable condition.

8.2.3 *Brakes*—Brakes shall be in serviceable condition and tested frequently to verify proper functioning.

8.2.4 *Payload*—The vehicle shall be free of any large payloads (liquid or solid) which may shift during braking.

9. Calibration and Standardization

9.1 *Calibration*—Calibrate the spot measuring decelerometer in accordance with the manufacturer's instructions.

9.1.1 The spot measuring decelerometer shall be returned to the manufacturer for servicing and calibration at a frequency recommended by the manufacturer. The interval between calibration adjustments shall not exceed two years.

9.2 *Self-Test*—For an electronic spot measuring decelerometer featuring a self-test capability: initiate a self-test prior to each test session in accordance with the manufacturer's instructions.

9.3 *Zero*—For a spot measuring decelerometer requiring a zero adjustment: adjust the zero reading prior to each test session in accordance with the manufacturer's instructions and confirm that the zero reading is maintained at the end of the test session.

10. Procedure

10.1 The following is the procedure for taking measurements of the frictional properties of winter contaminated pavement surfaces using a spot measuring decelerometer:

10.1.1 *Four-Wheel ABS Equipped Vehicles*—Disable the four-wheel ABS for the duration of the test on vehicles equipped with this system. (**Warning**—Disabling the four-wheel ABS will allow the front wheels to lock upon application of the brakes, resulting in a loss of directional control. Always ensure that no obstacles lay in the path of the vehicle prior to applying the brakes. Under most circumstances, releasing the force applied to the brake pedal will return directional control of the vehicle to the operator.)

10.1.2 Accelerate the vehicle to the required test speed (typically between 30 and 50 km/h (20 and 30 mph)) and apply the brakes in a gradual but firm manner so as to cause all the wheels to lock (front wheels only in the case of a vehicle equipped with rear-wheel ABS). Maintain wheel lockup until a valid measurement is obtained from the decelerometer. Follow manufacturer's instructions regarding whether or not the vehicle should be brought to a complete stop. (**Warning**—Locking the front wheels will result in a loss of directional control. Always ensure that no obstacles lay in the path of the vehicle prior to applying the brakes. Under most circumstances, releasing the force applied to the brake pedal will return directional control of the vehicle to the operator.) (**Warning**—Locking the rear wheels will place the vehicle in an unstable condition which may cause the vehicle to rotate "end-to-end". Always ensure that no obstacles lay in the path of the vehicle prior to applying the brakes. Under most circumstances, releasing the force applied to the brake pedal will return stability to the vehicle.)

10.1.3 Record the friction measurement and proceed to the next measurement.

10.1.4 Determine the friction index by averaging the prescribed number of friction measurements collected over a section of winter contaminated pavement.

10.2 The location, direction, test speed, and total number of friction measurements required depend on the type of pavement surface (highway or runway) and on any applicable regulations in effect.

10.2.1 *Minimum Number of Measurements*—A minimum of three friction measurements shall be taken in each section of winter contaminated pavement. The friction index shall be the average of the measurements taken over a section of winter contaminated pavement.

10.2.2 For friction measurements of winter contaminated runway pavements, the total runway length shall be divided into three equal segments. A minimum of three friction measurements shall be taken in each segment and an average friction index shall be determined for each segment.

11. Faulty Test

11.1 A measurement shall be deemed faulty and thus require a retest under the following conditions:

11.1.1 *Excessive Vehicle Yaw*—A measurement shall be canceled if the vehicle yaw exceeds 15° from the direction of travel at any time during braking.

11.1.2 *Patchy Conditions Encountered*—Measurements taken on patchy pavement surface conditions shall be taken on the contaminated surface. A measurement shall be canceled if the vehicle encounters a noticeable change in surface condition (or contaminant) during an individual braking event.

11.1.3 *Auto-Canceled Measurement*—Measurements canceled by the decelerometer shall require a new measurement.

11.1.4 *Self-Test or Zeroing Failed*—A self-test failure shall invalidate all measurements taken since the previous self-test. Failure of a decelerometer unit to return to its zero after a series of measurements shall invalidate all measurements taken since the zeroing operation.

11.1.5 *Four-Wheel ABS Activated*—Measurements taken with four-wheel ABS activated (where a vehicle with four wheel ABS is equipped with a method of disabling the four-wheel ABS) shall be invalidated.

12. Report

12.1 Report the following information:

12.1.1 *Test Location*—Location and identification of test section.

12.1.2 *Time of Test*—Date and time of day the test was performed.

12.1.3 *Operator Identification*—The name or identification of the operator performing the test.

12.1.4 *Friction Measurements*—The friction measurements for each test, as well as the friction index shall be reported. For runway pavements, the "thirds" averages, which are the

friction indices calculated over each of three sections of the runway, may be required.

12.1.5 *Surface Condition*—A short description of the pavement surface condition shall identify the predominant pavement friction problems and draw attention to conditions which may result in different braking action on various sections of the winter contaminated pavement (for example, patchy conditions).

12.1.6 *Ambient Temperature*—The ambient temperature at the time the testing was started.

12.2 It is recommended, but not required, that the following data be included in the test report:

12.2.1 *Decelerometer Identification*—The make, model number, and serial number of the spot measuring decelerometer.

12.2.2 *Decelerometer Calibration Date*—The date the last calibration was performed or the due date of the next calibration.

12.2.3 *Vehicle Type*—The vehicle make, model, year, serial number, and mass.

13. Precision and Bias

13.1 *Precision*—Limited information can be presented on the repeatability and reproducibility of this test method for measuring the frictional properties of winter contaminated pavement surfaces because of the impracticability of producing homogenous reference material. Insufficient data are available to determine the reproducibility standard deviation for spot measuring decelerometers of the same make and type, placed in different vehicles. However, testing has shown that the repeatability standard deviation for spot measuring decelerometers of the same make and type, placed in the same vehicle, can be expected to be between 0.02 to 0.04 g for a large number of non-homogenous winter contaminated surfaces. Furthermore, the same testing revealed that spot measuring decelerometers of the same make and type can be expected to produce measurements within 0.02 g of their mean for any single pass over a non-homogenous winter contaminated surface.

13.2 The relationship of the measured friction units to some "true" value of friction has not been studied at this time. Bias determinations are not possible due to the inability to establish a "true" value of friction for winter contaminated pavement surfaces.

14. Keywords

14.1 airport runway friction; braking; deceleration; decelerometer; tire pavement friction; winter conditions