Designation: E 2176 – 08

Standard Test Method for Measuring the Coefficient of Retroreflected Luminance of Pavement Markings in a Standard Condition of Continuous Wetting ($R_{L\text{-}Rain}$)[1]

This standard is issued under the fixed designation E 2176; 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 a measurement of the wet retroreflective ($R_{L\text{-}Rain}$) properties of horizontal pavement marking materials, such as traffic stripes and road surface symbols.

1.2 This method of measuring wet retroreflective properties (R_L) of pavement markings utilizes a method of continuously wetting the marking during measurement (see Fig. 1).

NOTE 1—Test Method E 2177 may be used to describe the retroreflective properties of pavement markings in conditions of wetness after a period of rain.

1.3 This test method is most suitable for laboratory use under controlled conditions, but may also be used for field measurements when the necessary controls and precautions are followed.

1.4 This test method specifies the use of reflectometers that can measure pavement markings per Test Method E 1710.[2] The entrance and observation angles required of the retroreflectometer in this test method are commonly referred to as "30 meter geometry."[2]

1.5 This test method has been shown to produce reasonable results for pavement marking systems with optics having an index of refraction greater than 2.0 and structured markings having vertical structures greater than or equal to 3 mm.[3] Users should exercise caution when using this test method for pavement marking systems with optics having an index of refraction less than 2.0 or markings having vertical structures less than 3 mm.

1.6 Results obtained using this test method should not be the sole basis for specifying and assessing the wet retroreflective effectiveness of pavement marking systems. Users should complement the results of this test method with other evaluation results, such as nighttime visual inspections.

1.7 *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.*

NOTE 2—An alternative test method designed to better represent the retroreflective efficiency of pavement marking systems under typical rain events is under development.

2. Referenced Documents

2.1 *ASTM Standards:*[4]

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

E 965 Test Method for Measuring Pavement Macrotexture Depth Using a Volumetric Technique

E 1710 Test Method for Measurement of Retroreflective Pavement Marking Materials with CEN-Prescribed Geometry Using a Portable Retroreflectometer

E 2177 Test Method for Measuring the Coefficient of Retroreflected Luminance (R_L) of Pavement Markings in a Standard Condition of Wetness

3. Terminology

3.1 *coefficient of retroreflected luminance, R_L*—the ratio of the luminance, L, of a projected surface to the normal illuminance, E, at the surface on a plane normal to the incident light, expressed in candelas per square metre per lux [(cd·m^{-2})/lx].

[1] This test method is under the jurisdiction of ASTM Committee E12 on Color and Appearance and is the direct responsibility of Subcommittee E12.10 on Retroreflection.

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[2] Reference ASTM E 1710. The standard measurement condition is intended to represent the angles corresponding to a distance of 30 m for the driver of a passenger car with an eye height of 1.2 m and a headlight height of 0.65 m above the road. See Appendix X1.

[3] The 3 mm minimum vertical structure height is based on a survey of materials evaluated and reported on in: FHWA/VTRC 05-CR3 Wet Night Visibility of Pavement Markings, VTRC (October 2004), FHWA/TX-06/0-5008-1 Evaluation of Wet-Weather Pavement Markings, First Year Report, TTI (Sept 2005), FHWA/TX-07/0-5008-2 Evaluation of Wet-Weather and Contrast Pavement Markings, Final Report, TTI (Aug 2007).

[4] 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.

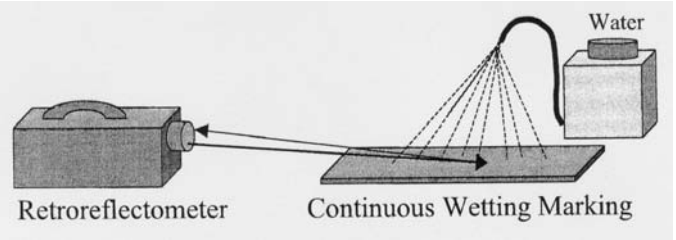

FIG. 1 Illustration of Measurement

Because of the low luminance of pavement markings, the units commonly used are millicandelas per square metre per lux [(mcd·m^{-2})/lx].

3.2 *conditions of continuous wetting*—the test condition is created by artificially creating rain by using a rain simulator such as a portable hand sprayer.

3.3 *external beam retroreflectometers*—retroreflectometers that illuminate a measurement area outside of the instruments body.

3.4 *internal beam retroreflectometers*—retroreflectometers that illuminate a measurement area inside of the instruments body.

3.5 *portable retroreflectometer*—an instrument that can be used in the field or laboratory for measuring the coefficient of retroreflected luminance, R_L.

3.6 $R_{L\text{-}Rain}$—the steady state retroreflectance value, R_L, obtained while the marking is being continuously wetted during the measurement (Fig. 2).

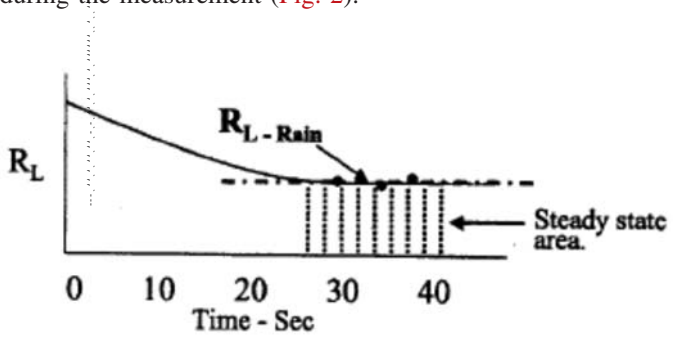

FIG. 2 Definition of $R_{L\text{-}Rain}$

4. Significance and Use

4.1 The coefficient of retroreflected luminance, R_L, is the property of a pavement marking system that provides a measure of the retroreflective efficiency of the marking and depends on factors such as the materials used, age, and wear pattern. These conditions shall be observed and noted by the user.

4.2 Under identical conditions of headlight illumination and driver's viewing, larger values of R_L correspond to higher levels of visibility at corresponding geometry.

4.3 The pavement marking's measured retroreflective efficiency in conditions of continuous wetting may be used to characterize the properties of the marking on the road as water is continuously falling on it. The retroreflective efficiency of the marking in conditions of continuous wetting may be different than in dry, wet or damp conditions.

4.4 This test method may produce measurements of $R_{L\text{-}Rain}$ for pavement marking systems that do not correlate to nighttime visibility distance during typical rain events. The rainfall intensity simulated by this test method is significantly greater than most ordinary or even heavy rainfall events. As a result, the test specimen, unless it has vertical features exceeding 3 mm, becomes flooded. Optics with an index of refraction less than 2.0 are practically ineffective when immersed in water. Thus, the test method is of limited applicability for assessing the wet retroreflective properties of pavement marking systems having vertical features less than 3 mm or optics having an index of refraction less than 2.0.

4.5 Retroreflectivity of pavement (road) markings degrades with traffic wear and requires periodic measurement to ensure that sufficient line visibility is provided to drivers.

4.6 Newly installed pavement markings may have a natural surface tension or release agents which prevent wetting of the marking by rain/water. This phenomenon produces unreliable and unrepeatable results when measuring retroreflective efficiency under wet conditions. This non-wetting phenomenon is generally eliminated after one month of wear and weathering on the road. A wetting agent can be used to estimate the $R_{L\text{-}Rain}$ properties of new markings (see 5.4).

4.7 Roadway characteristics such as longitudinal slope, cross slope and pavement porosity will impact the results of this test method.

5. Apparatus

5.1 *Retroreflectometer*:

5.1.1 The retroreflectometer shall be an external beam instrument and shall be designed and constructed so that stray light will not affect the reading.

5.1.2 The retroreflectometer shall meet the requirements of Test Method E 1710 (see Appendix X1).

5.2 *Retroreflectometer Setup—Rain/Water Shield*:

5.2.1 The retroreflectometer, if necessary, shall be modified with a rain/water shield to protect its lens from splattering rain/water during wet measurement.

5.2.2 Adjust the shield such that it does not block the projected light and diminish readings. Determine area of marking being illuminated with the projected light. Adjust shield so that it does not cover any of this area and thus prevent complete wetting.

5.3 *Rain Simulator (Water Sprayer)*:

5.3.1 The recommended rain simulator is a 8 L (2 gal) minimum capacity, adjustable nozzle garden sprayer. The rate of water spray should be approximately 0.8 L/min. A battery operated sprayer performs the best since the battery allows a constant rate/volume of water spray.

5.3.2 Clean tap water shall be used.

5.4 *Wetting Agent*:

5.4.1 The use of a wetting agent as explained herein is not a standard test procedure. However, the use of a wetting agent may be a practical way to estimate the performance of newly installed markings.

5.4.2 In that newly installed pavement markings may have a natural surface tension or release agents which prevent the wetting out of the product by rain/water, a practical method can be used to estimate the performance of newly placed markings.

The addition of a small amount of soap or surfactant to the water in the sprayer minimizes this interference without damage to the installed line or sample panel. Recommended solution mixtures are: (*a*) 0.10 % by volume liquid soap solution; and (*b*) a fluorocarbon surfactant solution, 1 mL in 8 L.

NOTE 3—Pavement markings that have been installed on the road for one month prior to testing usually do not exhibit this non-wetting phenomena. When testing new markings using the soap/surfactant agents above, visually examine the appearance of the marking as the water is applied. The water should not form small beads of water on top of the marking. If small beads are formed, increase the soap/surfactant level slightly and retry.

6. Sampling

6.1 The number of readings to be taken at each test location and the spacing between test locations shall be specified by the user.

6.2 Because of the unique nature of this test procedure, it is common to take less frequent measurements than one would do when assessing dry retroreflectance.

7. Standardization

7.1 The retroreflectometer shall be standardized using the instructions from the instrument manufacturer. A calibrated reference or working standard is used and is supplied with the instrument.

7.2 Transporting the portable retroreflectometer from an air conditioned area to the test site may result in fogging of mirrors in the instrument. If there is any doubt concerning the standardization or if the readings of the reference or working standard are not constant, allow the instrument to reach ambient conditions and re-standardize with the reference or working standard.

7.3 Verification must be made that there is no moisture on the retroreflectometer's lens when the instrument is being used for wet readings. Adjust the water protective shield as necessary.

7.4 *Standardization Recheck*—If the subsequent readings on the reference standard deviate by more than 5 % from the initial one, re-standardizaiton shall be performed. If the readings on the calibrated reference standard deviate by more than 10 % from the initial one, re-standardize and, in addition, re-measure previous measurements.

8. General Procedure

8.1 Both a dry and a wet measurement are usually taken in order to characterize the performance of the marking. The dry measurement establishes the effectiveness of the marking in a dry condition plus acts as a bench mark for the marking to which the wet performance can be compared. However, the dry measurement is optional per this test method.

8.2 *Measuring Dry Retroreflectance*:

8.2.1 Use the manufacturer's instructions for calibration and operation of the retroreflectometer.

8.2.2 Locate the area of the pavement marking to be measured.

8.2.3 Place the retroreflectometer squarely on the pavement marking material with the illumination in the direction of travel. Ensure that the illuminated measurement area of the retroreflectometer fits within the width of the stripe, and take a measurement.

8.3 *Measuring Wet Retroreflectance*:

8.3.1 If necessary, use a shield to prevent water splatter onto the lens of the retroreflectometer.

8.3.2 Position and adjust the water spray with the nozzle such that it provides an even spray covering the whole area to be measured. Confirm the spray area is being applied to the measurement area. The spray area should encompass a circle with a diameter of 510 ± 50 mm (20 ± 2 in.). Open the nozzle until the water rate is 0.8 ± 0.2 L/min. The pressure in the tank shall be maintained such that the flow does not noticeably diminish. Users should experiment with the sprayer to determine the best fill level that will allow maintenance of a constant pressure during use. The spraying height shall be 0.45 ± 0.15 m (18 ± 6 in.) above the marking.

NOTE 4—The most consistent spraying of the water has been found when using a battery operated portable sprayer. With this type of sprayer, the water rate is constant and the volume level in the tank does not effect the spray rate.

8.3.3 With the retroreflectometer still in place, the water spray is turned on, and the area of the marking to be measured and adjacent area (road) is wetted for at least 60 s.

8.3.4 Hold the water spray over the area of the marking to be measured and take a measurement. Continue to take measurements approximately every 15 s thereafter until little change in the values or a steady state occurs. This usually takes approximately 120 s to obtain a steady state value.

8.3.5 Record the measurements in millicandelas per square metre per lux, [(mcd·m^{-2})/lx]. Move to next measurement location which is separated sufficiently to provide meaningful data and repeat procedures 8.2 and 8.3.

NOTE 5—Verification must be made that there is no moisture on the lens when the instrument is being used for wet readings. Care must be taken when removing the moisture drops that a water smear is not left on the lens.

8.4 *Measuring Wet Reflectance Using a Wetting Agent*:

8.4.1 *Discussion*—The use of a wetting agent as explained herein is not a standard test procedure. However, the use of a wetting agent may be a practical way to estimate the performance of newly installed markings.

8.4.2 In order to wet out newly applied markings or to overcome release agents that may be present, a soap or surfactant may be added to the water spray to overcome this type of interference.

8.4.3 After the surfactant or soap has been added to the spray tank, the line is measured as in 8.3.

NOTE 6—Caution should be taken that bubbles are not created in the applied soap/water mixture as the bubbles act as interference.

9. Test Report

9.1 Include the following in the test report.

9.1.1 Test date, ambient temperature, and other weather conditions.

9.1.2 Identification of the instrument used, value and date of calibration of the reference standard panel used.

9.1.3 Operator name and contact information.

9.1.4 The measurement value in millicandelas per square metre per lux [(mcd·m^{-2})]/lx]. The measurements shall be reported for each marking location and direction of travel (as specified by the agency having jurisdiction).

9.1.5 Geographical location of the measurement site. Global positioning system (GPS) location or distance from the nearest permanent site identification, such as a mileage marker or crossroad.

9.1.6 Identification of the pavement marking tested: type (for example, binder type, thickness, bead type, bead size), color, age (date of pavement marking installation if known), location on road (edge line, first line, second line, centerline, etc.), and other information and characteristics as specified.

9.1.7 Description of road surface and road texture, that is, portland cement concrete (PCC) (broomed, brushed, worn), bituminous, chip seal, etc.

NOTE 7—Pavement texture may be identified and quantified by Test Method E 965.

9.1.8 Longitudinal and cross slope of roadway adjacent to measured pavement marking.

NOTE 8—Measurements should not be made where obvious puddling occurs due to lack of roadway drainage.

9.1.9 Remarks concerning the overall condition of the line, such as rubber skid marks, carryover of asphalt, snowplow damage, and other factors that may affect the retroreflection measurement.

10. Factors That May Influence Measurements

10.1 There are factors that may cause measurement variability when taking readings in the field. Some of these are:

10.1.1 Slight changes in the position of the retroreflectometer on or in front of the traffic line may yield different readings.

10.1.2 The rate of water spray, the area being wetted, and the height of the water spray should be controlled as much as possible to reduce measurement variability.

10.1.3 The initial values obtained with this test method are usually high and become lower until steady state is obtained. This process normally takes 60 to 120 s.

10.1.4 The ability of the water to wet the surface of the marking will affect the retroreflective readings. Normally newly installed pavement markings have a surface chemistry that causes water to "bead up" and act as reflective lenses. This will give higher measurement values. Therefore, initial readings are inflated and will show the marking's performance to be better than it will be after they have been on the road for a month, when the water wets out the marking. It is common practice to wait one month after installation to get a realistic value for the marking's performance (see 8.4 on using a surfactant).

TABLE 1 Repeatability in Conditions of Continuous Wetting (as described herein)—for $R_{L\text{-}Rain}$ Values Less than 100 [(mcd·m^{-2})/lx]

NOTE—Individual readings range from 0 to 103 [(mcd·m^{-2})/lx].

	n	Range of Values	Mean Value	Pooled St. Dev.	Coef. of Variation	95 % C.I. 2.8 (St. Dev.)
Study 1						
Instrument A	24	2 to 26	10.8	3.7	95.9 %	±10
Study 2						
Instrument B	14	4 to 39	14.6	1.8	35.0 %	±5.1
Study 3						
Instrument A	27	6 to 76	31.7	8.3	73.2 %	±23

TABLE 2 Repeatability in Conditions of Continuous Wetting (as described herein)—for $R_{L\text{-}Rain}$ Values Greater than 100 [(mcd·m^{-2})/lx]

NOTE—Individual readings range from 100 to 940 [(mcd·m^{-2})/lx].

	n	Range of Values	Mean Value	Pooled St. Dev.	Coef. of Variation	95 % C.I. 2.8 (St. Dev.)
Study 1						
Instrument A1	14	140 to 940	392	41.1	29.4 %	±115
Instrument A2	14	126 to 740	330	41.7	35.4%	±117
Study 3						
Instrument A1	20	103 to 568	319	40.9	35.8 %	±114

10.1.5 Water on the lens of the reflectometer will affect the readings. The lens must be keep clean and dry.

10.1.6 The longitudinal slope, and particularly the cross slope, of the roadway will influence the readings. More drainage (that is, greater slope) can result in higher readings. Measurements should be made where the slope is representative of the roadway.

11. Precision and Bias

11.1 The precision and bias is based on three separate studies conducted in conjunction with the 2000 NTPEP Pennsylvania State Test Deck, the 2001 study Wet Weather Visibility of Pavement Markings[5] and the 2000 CEN Wet Testing Study conducted in Hillerod, Denmark. The results can be found in Tables 1 and 2. The tables show the repeatability for two instrument types and for two levels of wet performance. One level of wet performance is shown in Table 1 for values less than 100 [(mcd·m^{-2})/lx] and the other level is shown in Table 2 for values greater than 100 [(mcd·m^{-2})/lx]. The calculations and results follow Practice E 691.

NOTE 9—The test procedure for the measurements forming the basis of the Test Method Repeatability and Reproducibility presented corresponded to the parameters of Test Method E 2176.

11.2 In each study, the wet reflective measurement was performed by first wetting the area of the marking to be measured and adjacent road and then continuously wetting the marking while taking the measurement. For each study, 3-5 replicate readings were obtained by simply triggering the instruments at 10 s intervals without moving the instrument once a steady state condition was obtained. The instruments were calibrated before the studies were conducted.

11.3 A reproducibility study (between instruments) has not been completed. However, in Table 2 for values of wet performance above 100 [(mcd·m^{-2})/lx], study #1 gives a comparison of two instruments (A1 and A2).

[5] Schnell, Aktan, Lee, Nighttime Visibility and Retroreflectance of Pavement Markings in Dry, Wet, and Rainy Conditions. Transportation Research Record 1824, Transportation Research Board of the National Academies, Washington, D. C., 2003.

12. Keywords

12.1 continuous wetting; dry retroreflection; pavement markings; portable retroreflectometer; wet retroreflection

APPENDIX

(Nonmandatory Information)

X1. EXAMPLES OF PAVEMENT MARKING MEASUREMENT SYSTEMS

X1.1 The entrance angle and observation angle specified in this test method are derived per the following geometry (which exists in the vertical plane only). (See Fig. X1.1.)

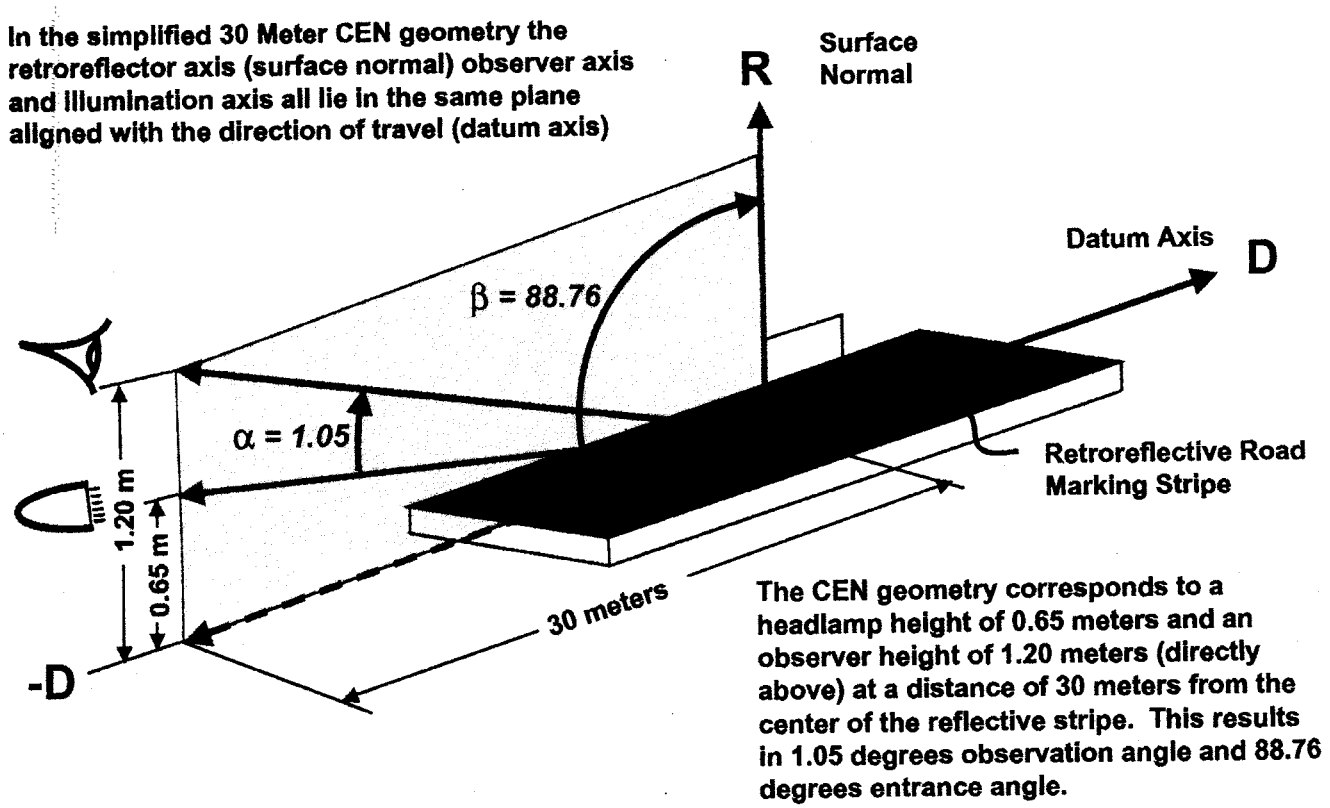

FIG. X1.1 CEN 30 Meter Geometry—Pictorial of Observation and Entrance Angles for Simplified CEN Car