Designation: E 2176 – 01

Standard Test Method for Measuring the Coefficient of Retroreflected Luminance (R_L) of Pavement Markings in a Standard Condition of Continuous Wetting[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 the measurement of the wet retroreflective (R_L) properties of horizontal pavement marking materials, such as traffic stripes and road surface symbols, using a portable or mobile retroreflectometer that can be placed on or before the road marking to measure the retroreflection at the prescribed geometry.

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

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

1.3 This test method specifies the use of portable or mobile 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]

1.4 This test method is intended to be used for field measurement of pavement markings but may be used to measure the performance of materials on sample panels before placing the marking material in the field.

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:*

D 6359 Specification for Minimum Retroreflectance of Newly Applied Pavement Marking Using Portable Hand-Operated Instruments[3]

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method[4]

E 965 Test Method for Measuring Pavement Macrotexture Depth Using a Volumetric Technique[3]

E 1710 Test Method for Measurement of Retroreflective Pavement Marking Materials with CEN-Prescribed Geometry Using a Portable Retroreflectometer[5]

E 2177 Test Method for Measuring the Coefficient of Retroreflected Luminance (R_L) of Pavement Markings in a Standard Condition of Wetness[5]

2.2 *Other Standards:*

CEN–EN 1436 Road Marking Materials—Road Marking Performance for Road Users[6]

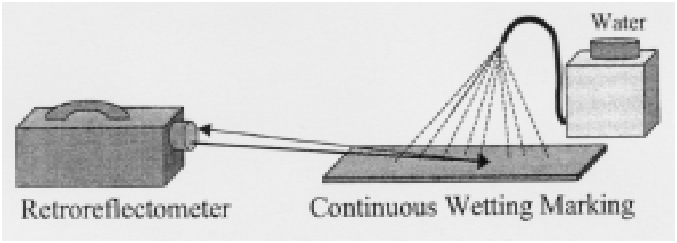

FIG. 1 Illustration of Measurement

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

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.

[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 "Standard Test Method for Measurement of Retroreflective Pavement Markings with CEN-Prescribed Geometry Using a Portable Retroreflectometer." 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] *Annual Book of ASTM Standards*, Vol 04.03.

[4] *Annual Book of ASTM Standards*, Vol 14.02.

[5] *Annual Book of ASTM Standards*, Vol 06.01.

[6] Available from European Committee for Standardization, Central Secretarial (CEN), rue de Stassart 36, B1050, Brussels, Belgium.

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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 *mobile retroreflectometer*—a retroreflectometer that has been mounted to a vehicle for purposes of taking measurements while the vehicle is moving.

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

3.7 $R_{L\text{-}Rain}$—The retroreflectance value, R_L, obtained while the marking is being continuously wetted during the measurement. See graph (Fig. 2). The value recorded is the average of two to three readings in the steady state area.

4. Significance and Use

4.1 The quality of the pavement marking is determined by the coefficient of retroreflected luminance, R_L, be it dry or wet, and depends on 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 visual performance at corresponding geometry.

4.3 The pavement marking's measured performance in conditions of continuous wetting may be used to characterize the performance of the marking on the road as water is continuously falling on it and may be representative to a period of rain. This performance of the marking may be different than that experienced when the markings are just wet or damp.

4.4 Retroreflectivity of pavement (road) markings degrades with traffic wear and requires periodic measurement to ensure that sufficient line visibility is provided to drivers. For example see Specification D 6359 for dry reflectivity requirements.

4.5 For a given viewing distance, measurements of R_L made with a retroreflectometer having a geometry corresponding to that viewing distance are a good indicator of the visual ranking of the material measured.

4.6 As specified by Test Method E 1710, the measurement geometry of the instrument is based on a viewing distance of 30 m, an eye height of 1.2 m and a headlight mounting height of 0.65 m (see Appendix X1).

4.7 Newly installed pavement markings may have a natural surface tension or release agents which prevent the wetting out of the product by rain/water. This phenomenon produces an interference when assessing the wet characteristics of a pavement marking. Attempt to measure markings with this surface "non-wetting" of the water may give higher values. This condition is short lived and markings that have been on the road for one month or more do not exhibit this non-wetting.

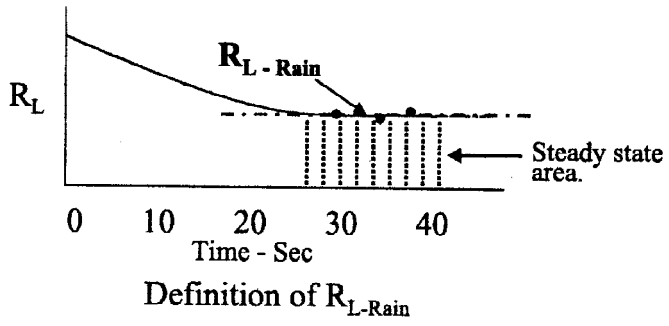

FIG. 2 Definition of $R_{L\text{-}Rain}$

4.8 It shall be the responsibility of the user to employ an instrument having the specified observation and entrance angles.

5. Apparatus

5.1 *Retroreflectometer—Portable or Mobile*:

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.

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 rain maker (simulator) shall be 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 *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.

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 eliminates 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 2—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.

6.3 Measurements for each line type shall be averaged for a final result.

7. Calibration

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

7.2 Transporting the portable reflectometer 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 calibration or if the readings of a reference or working standard are not constant, allow the instrument to reach ambient conditions and recalibrate with the reference or working standard.

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

7.4 *Calibration Recheck*—If the subsequent readings on the reference standard deviate by more than 5 % from the initial one, re-calibration shall be performed. If the readings on the reference standard deviate by more than 10 % from the initial one, recalibrate 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. Typically the spray area is approximately a 20 ± 2 in. circle. Open the nozzle until the water rate is approximately 0.8 ± 0.2 L/min. The pressure in the tank shall be maintained such that the flow does not noticeably diminish. Do not fill the sprayer too full of water so that one cannot keep a constant pressure. A range of ¼ to ¾ full works well. The spraying height shall be 0.45 ± 0.15 m (18 ± 6 in.) above the marking.

NOTE 3—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 in place, a reading shall be taken initially in the dry condition. (This is optional.)

8.3.4 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 10–15 s.

8.3.5 Hold the water spray over the area of the marking to be measured and take a measurement. Continue to take measurements approximately every 10 s thereafter until little change in the values or a steady state occurs. This usually takes about 30 s to obtain a steady state value.

NOTE 4—During the measurement process, the values obtained usually start high and will become lower until the steady state condition occurs.

8.3.6 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.

9.1.2 Average of the readings taken per line or marking expressed in millicandelas per square metre per lux [(mcd·m^{-2})/lx]. The average of the readings shall be reported for wet and for dry conditions and for each traffic direction of interest.

9.1.3 Readings for centerlines shall be taken for each direction of traffic. Readings for centerlines, edge lines, skip lines, etc., shall be averaged separately.

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

9.1.5 Identification of the pavement marking material tested: type, color, age, and the location on road (edge line, first line, second line, centerline, etc.).

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

9.1.7 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.

9.1.8 Ambient temperature and other weather conditions.

9.1.9 Description of roadway slope and general drainage where measurement is made (that is, puddles on marking due to low spot in road, water drained due to road incline, etc.)

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

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

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 reflectometer 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.

NOTE 8—It has been found that within the limits specified in this test method the affect of changes in the water spray rate, spray height, etc., is minimal.

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 20 to 30 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).

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

11. Precision and Bias

11.1 The precision and bias is based on three separate studies, and their 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.

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).

12. Keywords

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

TABLE 1 Repeatability in Conditions of Continuous Wetting—for Values of Wet Performance Under 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—for Values of Wet Performance Above 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

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.)

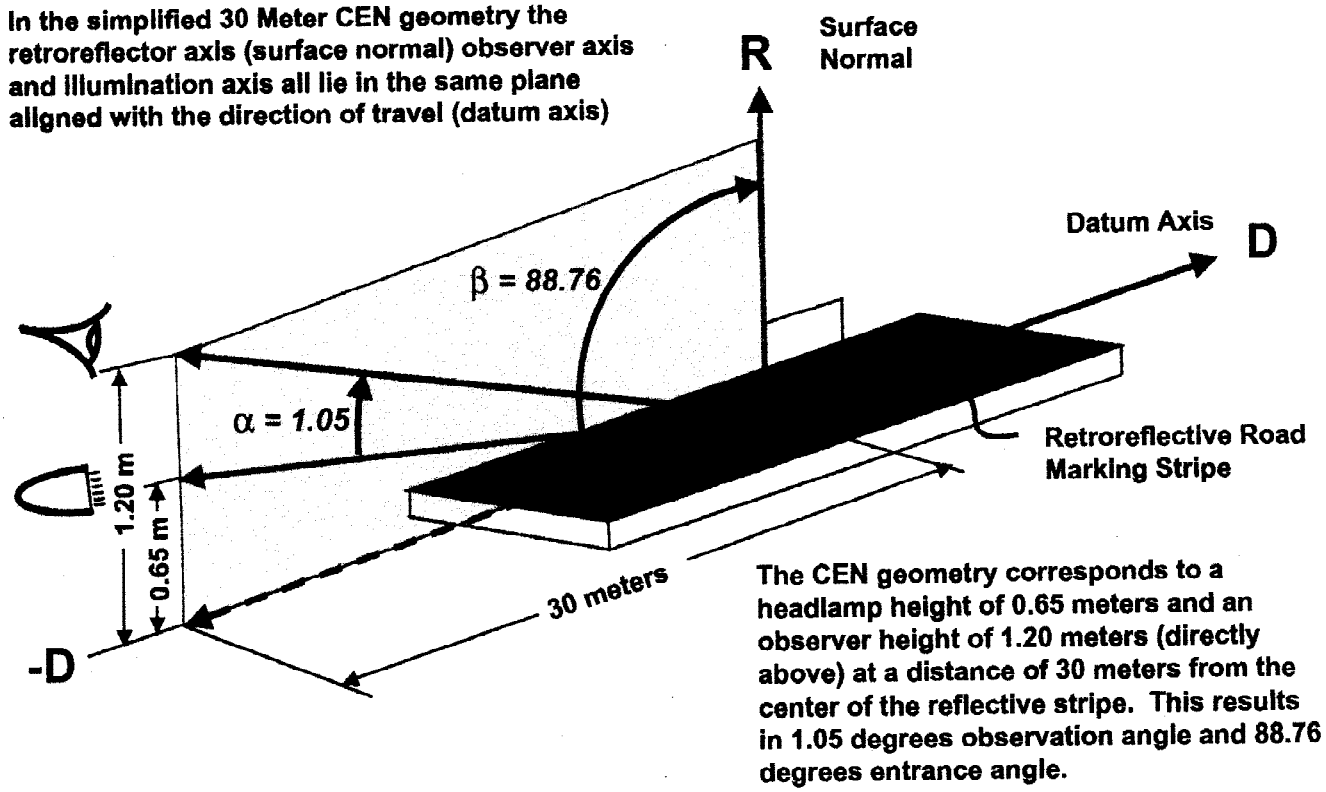

FIG. X1.1 CEN 30 Meter Geometry—Pictorial of Observation and Entrance Angles for Simplified CEN Car

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