Designation: E 2177 – 01

Standard Test Method for Measuring the Coefficient of Retroreflected Luminance (R_L) of Pavement Markings in a Standard Condition of Wetness[1]

This standard is issued under the fixed designation E 2177; 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 the wet retroreflective properties (R_L) of pavement markings measures the wet retroreflectivity in a standard condition of wetness (see Fig. 1).

1.2.1 *Discussion*—This test condition typically exists (*1*) after a rainfall has ended and the pavement markings are still wet or (*2*) as the markings are wet from dew or humidity.

1.3 Retroreflective performance obtained with this test in conditions of wetness does not necessarily relate to how markings perform in conditions of rain, that is, as markings are being rained upon.

NOTE 1—Test Method E 2176 defines a method to use to measure the performance of pavement markings in conditions of simulated rain.

1.4 This test method specifies the use of portable or mobile reflectometers that can measure pavement markings in accordance with 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 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[5]

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

E 2176 Test Method for Measuring the Coefficient of Retroreflected Luminance (R_L) of Pavement Markings in a Standard Condition of Continuous Wetting[5]

2.2 *Other Standard:*

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

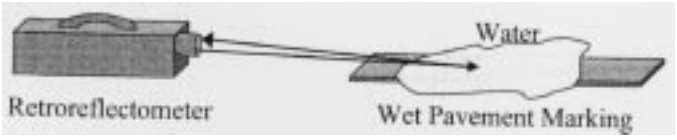

FIG. 1 Illustration of Measurement

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 *condition of wetness*—the test condition is created by liberally wetting the road marking and waiting a certain time period after wetting for water to run off.

3.2.1 *Discussion*—Similar conditions exist when road markings are wet or damp such as typically found after a rain has ended or from dew and high humidity.

3.3 *mobile retroreflectometer*—a retroreflectometer that has

[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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been mounted to a vehicle for purposes of taking measurements while the vehicle is moving.

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

3.5 *"recovery method" or "bucket method"*—alternative names commonly used to describe this test method for achieving measurements in condition of wetness.

3.6 $R_{L\text{-}wet}$—the retroreflectance value, R_L, obtained 45 s after wetting. (See Fig. 2.)

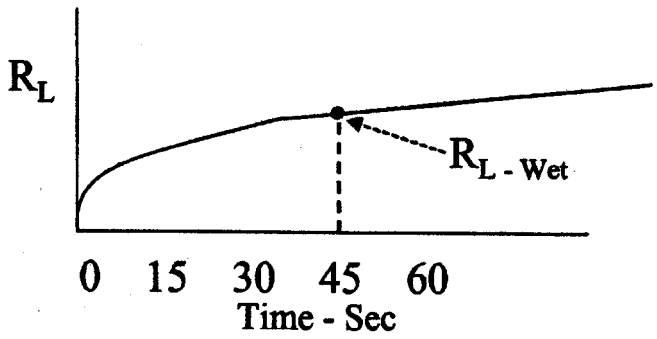

FIG. 2 Definition of $R_{L\text{-}Wet}$

4. Significance and Use

4.1 The nighttime performance of pavement markings 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 the same 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 the standard condition of wetness is used to characterize the performance of the marking on the road when wet.

4.4 Newly installed pavement markings may have a natural surface tension or release agents that prevent wetting of the product by water. The water will tend to "bead up" on the marking. This "non wetting" condition is usually short lived. Pavement markings that have been on the road for one month prior to testing usually do not exhibit this non-wetting phenomenon. (**Warning**–This phenomenon produces an interference when assessing the wet characteristics of a pavement marking. Attempts to measure markings with this surface "non-wetting" or "beading" of the water may give higher values.)

4.5 The retroreflectivity, R_L, 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 retroreflectivity requirements.

4.6 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.

4.7 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).

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

5. Apparatus

5.1 *Portable or Mobile Retroreflectometer*—The reflectometer must comply with Test Method E 1710.

5.2 *Stopwatch or Watch*, with second hand.

5.3 *Water*, for wetting the pavement marking.

5.3.1 A portable hand sprayer (garden sprayer) may be used to wet the pavement marking to create the wet condition. The portable hand sprayer shall have an adjustable nozzle. A battery operated unit works well.

5.3.2 Alternatively a bucket may be used to create the wet condition by pouring the water over the marking. Approximately 2 to 5 L of water are needed.

5.3.3 The water shall be clean tap water.

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 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 and Precautions

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 instrument's lens when the instrument is being used for wet readings. Sometimes the reflectometer's lens will become "fogged over" in high temperatures due to water evaporation. When roads are hot one can pre-cool the road with water before applying the test method to prevent the reflectometer from fogging.

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 or Wet Retroreflectance (R_L) of Markings*:

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 or in front of 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 Retroreflectance (R_L) in a Standard Condition of Wetness*:

8.3.1 Take a hand sprayer and wet the area of the marking to be measured and the adjacent surrounding area (road surface and marking) for 30 s. Verify that the marking and adjacent area are completely flooded. Or pour 2 to 5 litres of clean water from a bucket. Slowly pour the water over the area of the marking to be measured plus the immediate surrounding area. The water is poured evenly along the test surface so that the measuring field and its surrounding area is momentarily flooded by a crest of water (see Fig. 3).

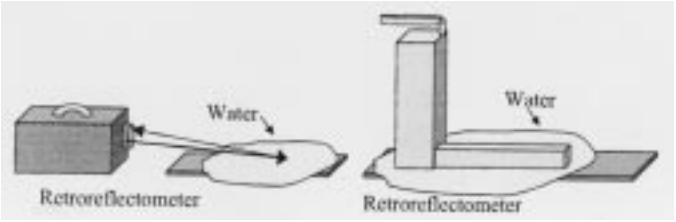

FIG. 3 Illustration of Measurement

8.3.2 Measure the coefficient of retroreflected luminance, R_L, of the wetted marking 45 ± 5 s after completion of spraying or pouring the water on the marking as described in 8.3.1 (see Fig. 3).

8.4 *Records*—Record the dry and wet 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 in 8.2 and 8.3.

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.

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 2—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 magnitude of the wet measurement obtained may sometimes be dependent upon how well the water drains ″off from″ the marking. Steep inclines will allow the water to run off quickly and lead to higher values. Conversely, low areas or dips will allow the water to puddle and will give lower values.

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 wetting the marking, waiting 45 s for the water to drain and then taking the measurement. For each study, 2-3 replicate readings were obtained by simply triggering the instruments a second or third time without moving the instrument (within 5 s). The wetting of the markings was done using a sprayer. The instruments were calibrated before the studies were conducted.

TABLE 1 Repeatability in Conditions of Wetness—for Values of Wet Performance Under 100 [(mcd·m^{-2})/lx]

NOTE 1—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	0 to 36	7.5	0.8	29.9 %	±2.2
Study 2						
Instrument A	17	4 to 98	52	4.2	22.7 %	±12

TABLE 2 Repeatability in Conditions of Wetness—for Values of Wet Performance Above 100 [(mcd·m^{-2})/lx]

NOTE 1—Individual readings range from 100 to 1174 [(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	97 to 1174	480	12.6	7.4 %	±35 mcd
Instrument A2	14	117 to 1150	460	14.6	8.9%	±41 mcd
Study 2						
Instrument A1	28	100 to 776	286	14.2	13.9 %	±40 mcd

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 dry retroreflection; mobile retroreflectometers; pavement markings; portable retroreflectometer; retroreflection in wet conditions

APPENDIX

(Nonmandatory Information)

X1. EXAMPLES OF PAVEMENT MARKING MEASURING 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.)

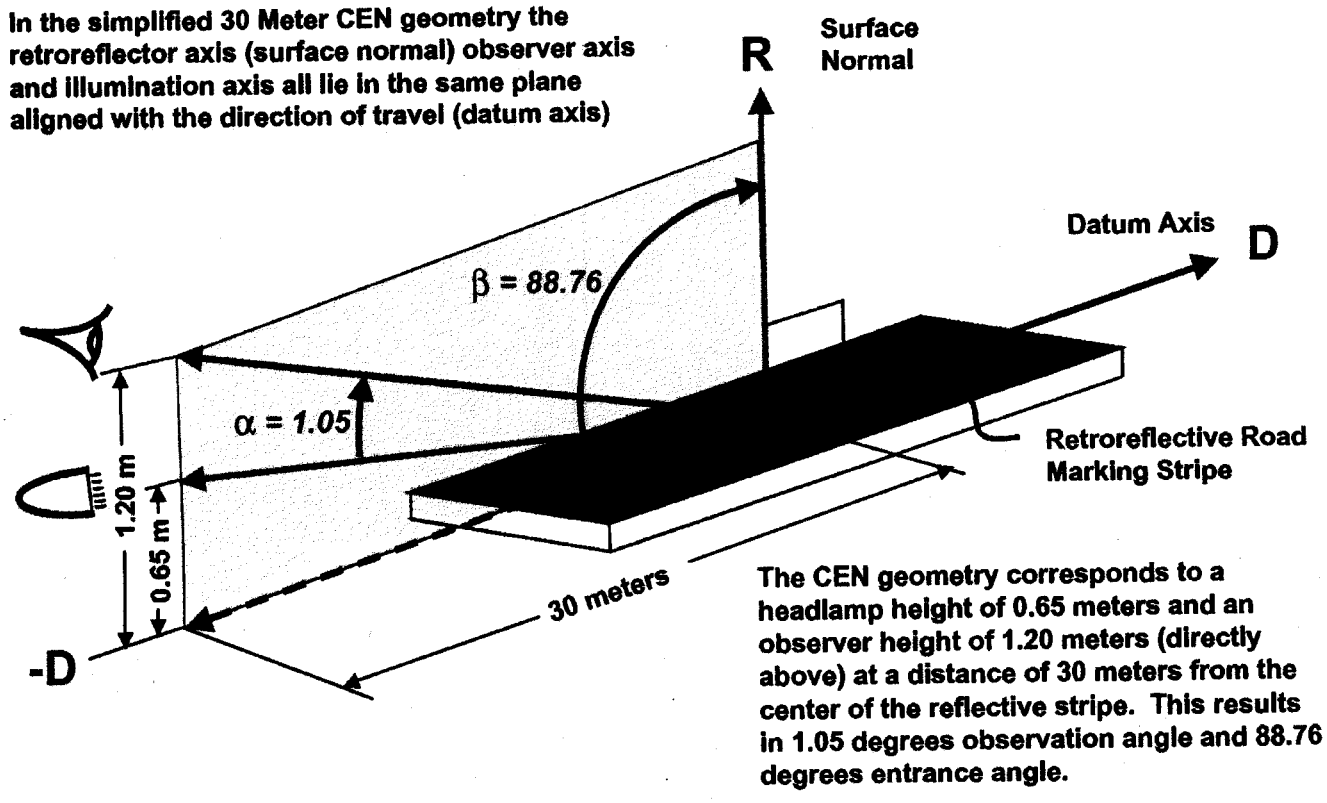

FIG. X1.1 CEN 30 Meter Geometry—Pictorial of Observation and Entrance Angles for Simplified CEN Car

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