Designation: E2177 – 11

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 E2177; 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 E2176 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 E1710.[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 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

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:*[3]

B965 Specification for High Performance Tin-Coated Annealed Copper Wire Intended for Electrical and Electronic Application for Solderability

D6359 Specification for Minimum Retroreflectance of Newly Applied Pavement Marking Using Portable Hand-Operated Instruments (Withdrawn 2006)[4]

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

E1710 Test Method for Measurement of Retroreflective Pavement Marking Materials with CEN-Prescribed Geometry Using a Portable Retroreflectometer

E2176 Test Method for Measuring the Coefficient of Retroreflected Luminance of Pavement Markings in a Standard Condition of Continuous Wetting ($R_{L\text{-}Rain}$) (Withdrawn 2013)[4]

2.2 *Other Standard:*

CEN–EN 1436 Road Marking Materials—Road Marking Performance for Road Users[5]

3. Terminology

3.1 *coefficient of retroreflected luminance, R_L, n*—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]. Because of the low luminance of pavement markings, the units commonly used are millicandelas per square metre per lux [(mcd·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 E1710 "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] 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.

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

[5] Available from European Committee for Standardization (CEN), 36 rue de Stassart, B-1050, Brussels, Belgium, http://www.cenorm.be.

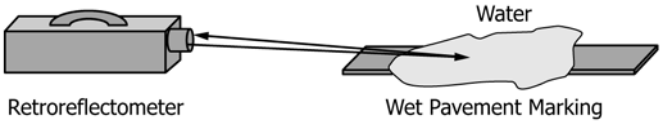

FIG. 1 Illustration of Measurement

3.2 *condition of wetness, n*—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, n*—a retroreflectometer that has been mounted to a vehicle for purposes of taking measurements while the vehicle is moving.

3.4 *portable retroreflectometer, n*—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", n*—alternative names commonly used to describe this test method for achieving measurements in condition of wetness.

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

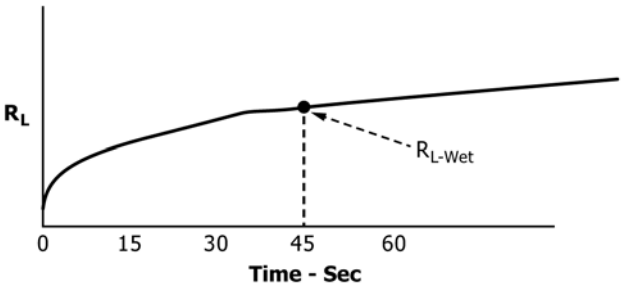

FIG. 2 Definition of $R_{L\text{-}Wet}$

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 D6359 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 E1710, 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 E1710.

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).

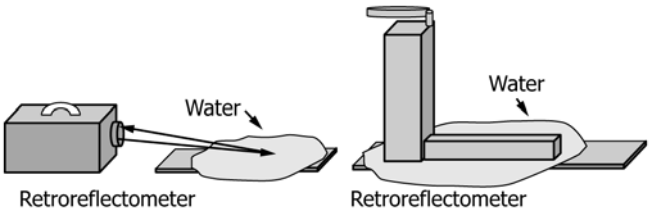

FIG. 3 Illustration of Measurement

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 B965.

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[6]

11.1 The precision of this test method is based on an interlaboratory study of ASTM E2177, Standard Test Method

[6] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:E12-1004. Contact ASTM Customer Service at service@astm.org.

TABLE 1 Results of Precision Testing for Coefficient of Retroreflected Luminance of Pavement Markings in a Standard Condition of Wetness (mcc/lx/m^2)

Sample	Average of the Labs' Averages	Repeatability Standard Deviation s_r	Reproducibility Standard Deviation S_R	Repeatability Limit r	Reproducibility Limit R	R/mean
O	85.7	6.4	7.3	17.9	20.4	24 %
R	737.4	52.3	65.2	146.4	182.6	25 %
H	307	14.4	31.4	40.2	87.9	29 %
D	197.3	15.9	24.8	44.4	69.4	35 %
Q	1328.7	155.3	181.8	434.7	509.1	38 %
K	164.6	20.6	23.6	57.7	66.1	40 %
N	76.9	11.2	13	31.3	36.4	47 %
F	166.1	23.5	36	65.8	100.9	61 %
At	114.6	27.5	37.7	77.1	105.7	92 %

for Measuring the Coefficient of Retroreflected Luminance (R_L) of Pavement Markings in a Standard Condition of Wetness, conducted in 2010. Ten laboratories participated in this study. Each of the labs was asked to report fifteen replicate test results for ten different materials. Every "test result" reported represents a single determination or measurement. Practice E691 was followed for the design and analysis of the data; the details are given in ASTM Research Report No. RR:E12-1004.

11.1.1 *Repeatability Limit (r)*—Two test results obtained within one laboratory shall be judged not equivalent if they differ by more than the "*r*" value for that material; "*r*" is the interval representing the critical difference between two test results for the same material, obtained by the same operator using the same equipment on the same day in the same laboratory.

11.1.1.1 Repeatability limits are listed in Table 1.

11.1.2 *Reproducibility Limit (R)*—Two test results shall be judged not equivalent if they differ by more than the "*R*" value for that material; "*R*" is the interval representing the critical difference between two test results for the same material, obtained by different operators using different equipment in different laboratories.

11.1.2.1 Repeatability limits are listed in Table 1.

11.1.3 The above terms (repeatability limit and reproducibility limit) are used as specified in Practice E177.

11.1.4 Any judgment in accordance with statements 11.1.1 and 11.1.2 would have an approximate 95 % probability of being correct.

11.2 *Bias*—At the time of the study, there was no accepted reference material suitable for determining the bias for this test method, therefore no statement on bias is being made.

11.3 The precision statement was determined through statistical examination of 1449 results, from ten laboratories, reporting up to fifteen replicate analyses, on a total of ten different materials, which were described as:

At: AASHTO M247 Type II beads on thermoplastic
D: AASHTO M247 Type III beads on water-based paint
F: AASHTO Type III and V beads on profiled thermoplastic
H: AASHTO Type I and IV beads on inverted profile thermoplastic
K: Cluster-style optics on polyurea
N: AASHTO Type I beads on profiled MMA
O: Preformed tape
Q: Preformed tape
R: Preformed tape

11.4 To judge the equivalency of two test results, it is recommenced to choose the material closest in characteristics to the test specimen.

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.)

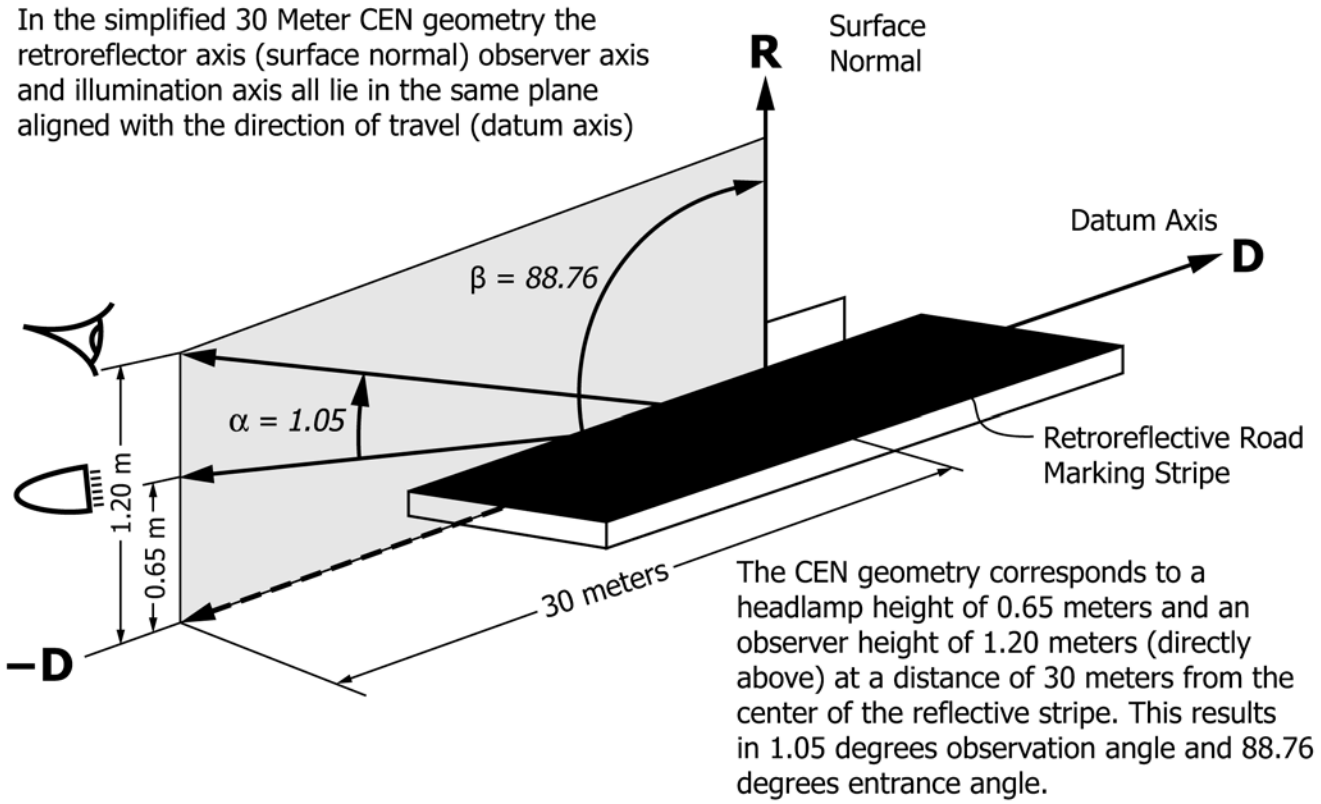

FIG. X1.1 CEN 30 Meter Geometry—Pictorial of Observation and Entrance Angles for Simplified CEN Car