Designation: E2832 – 12

Standard Test Method for Measuring the Coefficient of Retroreflected Luminance of Pavement Markings in a Standard Condition of Continuous Wetting (R_{L-2})[1]

This standard is issued under the fixed designation E2832; 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-2}) properties of horizontal pavement marking materials, such as traffic stripes and road surface symbols. A standardized method utilizing a standardized continuous wetting device and a portable retroreflectometer is described to obtain measurements of the wet retroreflective properties of horizontal pavement markings.

1.2 Retroreflective performance obtained with this test in a standardized condition of continuous wetting does not necessarily relate to how markings perform in all conditions of natural rain.

NOTE 1—Test Method E2177 may be used to describe the retroreflective properties of pavement markings in conditions of wetness, such as after a period of rain.

1.3 This test method is suitable for measurements made in the laboratory and in the field when the necessary controls and precautions are followed.

1.4 This test method specifies the use of external beam retroreflectometers conforming to 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 test method excludes the effects of rain between the vehicle and the marking.

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 The values stated in SI units are to be regarded as standard. The values given in parentheses are for information only.

1.8 *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]

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

E965 Test Method for Measuring Pavement Macrotexture Depth Using a Volumetric Technique

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

E2177 Test Method for Measuring the Coefficient of Retroreflected Luminance (R_L) of Pavement Markings in a Standard Condition of Wetness

3. Terminology

3.1 *Definitions:*

3.1.1 *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 millicandelas per square metre per lux (mcd/m^2/lx).

3.1.2 *conditions of continuous wetting, n*—the test condition where the pavement marking specimen is subjected to continuously uninterrupted water spray applied uniformly over a pavement marking at a defined and controlled rate during measurement.

[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 Test Method E1710. 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 Annex A1.

[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.

3.1.3 *external beam R_L retroreflectometers, n*—a pavement marking retroreflectometer that measures the coefficient of retroreflected luminance, R_L, in a measurement area that falls entirely outside the retroreflectometer.

3.1.4 $R_{L\text{-}2}$, *n*—the steady state coefficient of retroreflected luminance, R_L, determined under defined conditions of continuous wetting at a rate of 2 inches per hour.

3.1.4.1 *Discussion*—The results from this test method shall be reported as $R(_{L\text{-}2})$ where "2" designates the wetting rate used in inches per hour (in./h).

3.1.5 *steady state conditions, n*—the measurements have reached steady state when six consecutive retroreflectometer instrument readings made at approximately 10 s intervals show no consistent tending of the coefficient of retroreflected luminance value up or down.

4. Summary of Test Method

4.1 This test method describes a standard procedure for measuring the retroreflective properties of horizontally applied pavement marking systems under conditions of continuous wetting.

4.2 The pavement marking system under test is subjected to continuous wetting delivered by a wetting device of a specified design calibrated to provide a controlled wetting rate.

4.3 A protocol and instrument requirements are described for measuring $R_{L\text{-}2}$ under a defined condition of continuous wetting.

5. Significance and Use

5.1 This test method produces a measure of retroreflective efficiency (coefficient of retroreflected luminance, $R_{L\text{-}2}$) for a pavement marking system under conditions of continuous wetting. The test result depends on factors such as the pavement marking binder and optic materials, their application, wear from traffic and plowing, wetting rate, and road grade and cross slope.

5.2 The measured retroreflective efficiency under conditions of continuous wetting may be used to characterize the properties of a pavement marking on the road as water is continuously falling on it. The retroreflective efficiency of the marking under conditions of continuous wetting is almost always different than under dry conditions.

5.3 The wetting rate of 2 in./h represents the upper limit of what is meteorologically classified as heavy rainfall. Rainfall rates above 2 in./h are classified as extreme or violent, and are sometimes associated with weather such as tropical storms.

5.4 The retroreflectivity of pavement markings degrades with traffic wear and requires periodic measurement to ensure that the coefficient of retroreflected luminance under continuous wetting meets requirements and provides adequate visibility for nighttime drivers.

5.5 The continuous wetting rate as well as the roadway grade and cross slope impact the results of this test method. The user shall measure and report the rate used for testing.

5.6 The roadway grade and cross slope adjacent to the measurement area impact the results of this test method. A digital level (inclinometer) can be used to quickly measure grade and cross slope.

5.7 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.

6. Interferences

6.1 Newly installed pavement markings may have surface properties that prevent uniform wetting. This hydrophobic condition can produce inconsistent and highly variable results when measuring the coefficient of retroreflected luminance under continuous wetting conditions.

6.1.1 It is recommended that measurements be made at least 14 days after markings are applied. Hydrophobic conditions are generally eliminated by exposure to the environment and wear of traffic.

6.1.2 For laboratory measurements of pavement marking systems installed on panels, particular care must be taken to avoid hydrophobic conditions, since the panels are typically not exposed to traffic. The use of a surfactant in the water reservoir has created problems of microscopic foaming and bubbles, resulting in unacceptable variability in readings. More testing is needed before a specific surfactant can be recommended.

7. Apparatus

7.1 *Retroreflectometer:*

7.1.1 The retroreflectometer shall be an external beam R_L retroreflectometer (see 3.1.3).

7.1.2 The retroreflectometer shall have such dimensions and location of the measurement area such that the retroreflectometer can be placed relative to the wetting device so that the measurement area falls entirely within the wetted area inside the wetting device.

7.1.3 The retroreflectometer shall meet the requirements of Test Method E1710.

7.2 *Wetting Device:*

7.2.1 The wetting device shall conform to the design and operating parameters in Annex A1.

NOTE 2—Water drop size and velocity at impact will impact retroreflected luminance measurements of markings. The wetting apparatus described in Annex A1 has particular water impact characteristics that have not been quantified. In order to measure the retroreflected luminance measurements of markings under conditions of continuous wetting in a standard way, the design and construction of the wetting device described in Annex A1 must be followed.

8. Reagents and Materials

8.1 Clean water free of particulate and dissolved solids shall be used to prevent clogging of the nozzles. Commercial distilled drinking water is recommended.

9. Sampling, Test Specimens, and Test Units

9.1 For field measurements, the test specimens selected shall be visually representative of the pavement marking to be evaluated and free of obvious excessive wear such as skid marks or plow damage.

9.2 Although only one test specimen is required, multiple test specimens are recommended.

9.3 Measurements shall be recorded only after steady state conditions have been achieved. Record a minimum of four instrument readings before moving the wetting apparatus.

10. Calibration and Standardization

10.1 *External Beam Retroreflectometer:*

10.1.1 The retroreflectometer shall be standardized according to the instructions from the instrument manufacturer using the calibrated reference or working standard supplied with the instrument.

10.1.2 Transporting portable retroreflectometers 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. If the problem persists, suspend the measurements until the instrument can be repaired.

10.1.3 The standardization of the instrument shall be re-verified at least once per day under dry conditions. If the subsequent readings on the reference standard deviate by more than five percent from the reference value, re-standardization shall be performed. If the readings on the reference standard deviate by more than ten percent from the reference value, re-standardize and, in addition, repeat all measurements made subsequent to the prior successful verification or standardization.

10.2 *Wetting Device:*

10.2.1 Calibration of the wetting rate shall be performed prior to any measurements. Adjust the nozzle angle and operating pressure until the required continuous wetting rate is achieved.

10.2.2 Center three adjacently placed dry containers of known opening area (each measuring approximately 100 mm (4 in.) wide by 100 mm (4 in.) long) over the retroreflectometer measurement area (the containers shall be at least 12.5 mm (0.5 in.) deep). Turn on the wetting device and collect water for at least two minutes. Determine the volume of water using one of the following procedures.

10.2.2.1 *Volumetric Method*—Pour the contents of each container into a dry 50 mL graduated cylinder. Record the volume of water collected to the nearest 0.1 mL in each individual container. Divide the volume of water by the collection time in minutes. Record the volume per minute in mL/min.

10.2.2.2 *Gravimetric Method*—Prior to the calibration, weigh each dry container and record its tare weight to the nearest 0.1 g. After collecting the water spray, reweigh and record the gross weight of each container. Calculate the net weight of water collected by subtracting the tare weight from the gross weight. Divide the net weight of water collected in each container by the density of water (1.0 g/mL) to obtain the volume of water collected in each container. Divide the volume of water by the collection time in minutes. Record the volume per minute in mL/min.

10.2.3 *Wetting Rate Calculation*—Calculate the wetting rate for each container from Eq 1. The required wetting rate is 2.0 ± 0.2 in./h.

$$Wetting\ Rate\ (in./h) = (VPM/Area)*0.394\ (in./cm)*60\ (min./h) \quad (1)$$

where:

VPM = volume per minute, in mL/min; and
Area = container opening area, in cm^2.

10.2.4 To check the spray pattern for uniformity across the measurement area, compare wetting rates calculated for the three containers. The wetting rates measured for each individual container shall be within 20 percent of the average wetting rate of the three containers.

10.2.5 The wetting rate and uniformity of spray shall be checked regularly. It is recommended that the wetting rate and uniformity of spray should be verified at least daily and prior to taking measurements. If the spray pattern or wetting rate changes, check the nozzles for debris that may have accumulated. The nozzles shall be cleaned and the wetting rate rechecked. A visual inspection of the spray pattern can be helpful to identify non-uniform spray and the need to clean the nozzles.

10.2.6 A light trap shall be installed opposite the retroreflectometer opening to reduce stray light from positively biasing the measurement. To determine if the light trap is functioning as desired, position the retroreflectometer and wetting apparatus over a flat pavement surface without retroreflective markings. Once the pavement surface is saturated and while the wetting device is operating at the desired wetting rate, record a reading. The reading must be less than 5 mcd/lx/m^2 when no retroreflective marking is present.

11. Procedure

11.1 Measure the grade and cross slope of the pavement adjacent to the test specimen.

11.1.1 Measurements in the field shall not be made where both the cross slope and grade are less than 0.5 percent, or where the water submerges the test specimen.

11.1.2 Measurements in the laboratory shall be made with the test specimen resting on a two percent cross slope and a one percent grade.

11.2 Place the wetting device on the test specimen making sure that the wetting area is aligned with the test specimen.

11.3 Turn on the wetting device pump, check the pressure, and verify that the test specimen is being uniformly wetted at a rate of 2.0 ± 0.2 in./h.

11.4 With the wetting device in position, gently place the retroreflectometer in position so that it can measure through the opening in the wetting device.

11.5 Allow the wetting device to operate long enough to saturate the test specimen. This may take 30 seconds to several minutes, depending on the type of marking and whether Test Method E2177 was run on the same specimen immediately prior to the running of this test (which is generally considered to be a good practice). Once the marking has been saturated, continue operating the wetting device and begin taking instrument readings at ten second intervals until the retroreflective

TABLE 1 Results of Precision Testing for Coefficient of Retroreflected Luminance in a Standard Condition of Continuous Wetting (mcd/lx/m²)

Test	$\bar{x}$	$s\bar{x}$	S_r	s_R	r	R	R/mean
5	394.1	28.1	32.7	36.4	91.6	102.0	26 %
6	558.7	61.2	49.1	70.3	137.6	197.0	35 %
10	137.4	17.8	13.2	20.1	37.0	56.3	41 %
9	149.1	25.9	23.8	30.9	66.6	86.5	58 %
4	156.7	25.0	32.2	33.8	90.1	94.7	60 %
7	137.1	37.7	11.3	38.6	31.7	108.0	79 %
8	186.1	58.3	17.6	59.6	49.2	166.8	90 %
3	79.6	24.6	19.2	28.1	53.8	78.7	99 %
2[A]	8.6	3.4	2.8	3.9	7.8	11.0	128 %
1[A]	9.9	4.3	2.7	4.8	7.7	13.3	135 %

[A] This pavement marking system is not traditionally considered to have wet retroreflective performance.

values reach a steady state condition. If the markings do not reach a steady state condition within five minutes, then the results shall be reported as undetermined.

11.6 Once steady state conditions have been achieved, begin recording instrument readings for each test specimen. Record a minimum of four readings.

12. Calculation or Interpretation of Results

12.1 To determine the test results, calculate the average value of four consecutive instrument readings per test specimen. Include separate test results if the measurements were made for each direction of traffic for centerlines.

13. Report

13.1 The report shall include the following items:

13.1.1 Test date, ambient temperature, and other pertinent weather conditions.

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

13.1.3 Operator name and contact information.

13.1.4 The continuous wetting rate and average and standard deviation of the test result reported in millicandelas per square metre per lux (mcd/m²/lx). The test result shall be reported for each test specimen and direction of travel (as specified by the agency having jurisdiction). If multiple wetting rates are used, they shall be reported independently.

13.1.5 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.

13.1.6 Identification of the pavement marking tested; type (for example, binder type, thickness, and optical media which might include bead type and bead size if known), color, age (date of pavement marking installation if known), location on road (edge line, first line, second line, center line, etc.), and other information and characteristics as specified.

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

NOTE 3—Pavement texture may be identified and quantified by Test Method E965.

13.1.8 Grade and cross slope of roadway adjacent to measured pavement marking.

13.1.9 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.

14. Precision and Bias[4]

14.1 The precision of this test method is based on an interlaboratory study of ASTM E2832, Test Method for Measuring the Coefficient of Retroreflective Luminance of Pavement Markings in a Standard Condition of Continuous Wetting ($R_{L\text{-}2}$), conducted in 2011. Ten laboratories participated in this study. Each of the labs was asked to report two replicate test results for two locations on five different thermoplastic pavement marking systems. 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 Research Report No. RR:E12-1007.

14.1.1 *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.

14.1.1.1 Repeatability limits are listed in Table 1.

14.1.2 *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.

14.1.2.1 Reproducibility limits are listed in Table 1.

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

14.1.4 Any judgment in accordance with statements 14.1.1 and 14.1.2 would have an approximate 95 % probability of being correct.

14.2 *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.

[4] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:E12-1007. Contact ASTM Customer Service at service@astm.org.

14.3 The precision statement was determined through statistical examination of 200 results, from ten laboratories, reporting up to two replicate analyses, on a total of ten different test locations on five different pavement marking materials, which were described as:

Test 1 and 2: Thermoplastics with a single drop of AASHTO M247 Type 1 beads;

Test 3 and 4: Thermoplastics with a double drop of Type 3 beads and 3M[5] reflective elements;

Test 5 and 6: Inverted Rib Thermoplastics with a double drop of Type 1 and glass beads with an index of refraction of 1.9;

Test 7 and 8: Thermoplastics with a double drop of Type 1 and 4 beads; and

Test 9 and 10: Thermoplastics with a double drop of Type 3 and Potter's Visimax[6] beads.

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

15. Keywords

15.1 continuous wetting; pavement markings; wet retroreflection

[5] 3M is a registered trademark of the 3M Company.

[6] Visimax is a registered trademark of VisiMax Technologies.

ANNEXES

(Mandatory Information)

A1. PORTABLE POWERED CONTINUOUS WETTING DEVICE DESIGN MANUAL

INTRODUCTION

This standard details the construction of the wetting device for use in determination of Coefficient of Retroreflected Luminance of Pavement Markings in a Standard Condition of Continuous Wetting ($R_{L\text{-}2}$). The device consists of a portable water storage system, a battery operated pump attached to a mount, and a handheld enclosed spray box. The following sections describe the construction and operation of the device.

A1.1 Construction Details

A1.1.1 A portable water reservoir consisting of a backpack sprayer is used in the construction (Fig. A1.1). It consists of the tank, support framing, spray wand, and pump lever. The latter two items, the spray wand and pump lever, were removed.

A1.1.1.1 *Step 1*: Remove Spray Wand. If present, remove the spray wand and pump lever from sprayer.

A1.1.1.2 *Step 2*: Remove Pump Assembly. If present, remove the hand operated pump and pump rod. Open the storage tank and remove the pressure valve inside the storage tank.

A1.1.1.3 *Step 3*: Assemble Pressure Regulator. All 11 parts of the pressure regulatory are shown in Fig. A1.2(a). Thread the 1 in. threaded bushing (#1) into the tank where the pump was removed. Assemble parts #2 through #11 before attaching to part #1. The pressure valve and gauge will fit very close to the tank. Fig. A1.2(b) is a depiction of the pressure regulator attached to the storage tank.

NOTE A1.1—Dry fit and make sure all connections are tight and fit properly before gluing #2 bushing into #1 bushing. After the two bushings are glued up you will not be able to disassemble without cutting some parts.

A1.1.1.4 *Step 4*: Install Pump and Power. Install the pump and power supply. The pump and power supply need hard mounting points, so mounting plates must be fabricated, such as the ones shown in Fig. A1.3(a). Mounting hardware to attach the mounting plates is shown in Fig. A1.3(b). Mount the pump and attach lines and filter as shown in Fig. A1.4.

NOTE A1.2—Filter is directional and shown in the close-up image in the top left of Fig. A1.4.

(a) Fabricate a mounting bracket for a power switch. Mount the battery and power switch. The power switch and its assembly are shown installed to the fabricated battery storage tray in Fig. A1.5(a). Fig. A1.5(b) shows an image of the pump and power supply installed.

A1.1.1.5 *Step 5*: Fabricate Spray Box. It is recommended to have the spray box fabricated out of corrosion resistant sheet metal such as aluminum to minimize weight. Fig. A1.6 shows images of a fabricated spray box. Fig. A1.6(c) is a close-up of some of the rigid supports that were installed to add stability of the spray box.

(a) Images of the nozzle parts are shown in Fig. A1.7. It is important to note that the filter (#4) will help with minimizing debris clogging the nozzles, but it is recommended to use water with minimal sediment and to regularly clean and maintain the nozzles to ensure consistent operation. It is recommended to have 1 or 2 spare nozzles when in the field to minimize measurement delay.

(b) Once the nozzle is assembled it can be attached to the spray box. Fig. A1.8 contains several pictures of the various points of interest with regard to the installation of the spray nozzle. Locate the nozzle tip 8 in. (±0.125 in.) from the bottom

of the spray box. This will require mounting the bracket slightly lower and offset from the center to achieve the proper nozzle tip location. Aim the nozzle up (25 degrees from vertical ±5.0 degrees) and toward the center of the box (see Fig. A1.8(b) and (c)).

(c) Fig. A1.8(c) shows the light trap made from a stiff foam wedge cut at a 60 degree angle with the exposed face painted flat black. Fig. A1.8(d) shows the sloped drip channel above the measurement opening. The completed wetting apparatus is shown in use in Fig. A1.9.

A1.2 System Operation

A1.2.1 Always make sure that sufficient water is in the reservoir so that air and debris do not get into the lines and impact the wetting rate. Operate the wetting device at 23 ± 2 psi. Visually inspect the spray pattern to detect obstructions that may have entered the nozzles or water lines. See Section 10 for Calibration.

FIG. A1.1 Typical Backpack Hand-Pump Sprayer