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AMERICAN SOCIETY FOR TESTING AND MATERIALS
100 Barr Harbor Dr., West Conshohocken, PA 19428
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Standard Test Method for Measurement of Retroreflective Pavement Marking Materials with CEN-Prescribed Geometry Using a Portable Retroreflectometer[1]

This standard is issued under the fixed designation E 1710; 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 measurement of the retroreflective properties of horizontal pavement marking materials containing retroreflecting beads, such as traffic stripes and surface symbols, using a portable retroreflectometer that can be placed on the road delineation to measure the retroreflection at a prescribed geometry.

NOTE 1—The restriction to bead based materials is for the purpose of ensuring a sufficiently gradual optical response function (from points of the source aperture to points of the receiver aperture) to allow generous sized instrument source and receiver apertures.

1.2 The entrance and observation angles of the retroreflectometer affect the readings. As specified by the European Committee for Standardization (CEN), the entrance and observation angles shall be 88.76° and 1.05°, respectively.

1.3 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.

1.4 *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 4061 Test Method for Retroreflectance of Horizontal Coatings[2]

E 284 Terminology of Appearance[2]

E 809 Practice for Measuring Photometric Characteristics of Retroreflectors[2]

2.2 *Other Standard:*

CEN EN 1436 Road Marking Materials—Road Marking Performance for Road Users[3]

3. Terminology

3.1 The terminology used in this test method generally agrees with that used in Terminology E 284.

3.2 *Definitions*—The delimiting phrase "in retroreflection" applies to each of the following definitions when used outside the context of this or other retroreflection test methods:

3.2.1 *coefficient of retroreflected luminance, R_L, n*—the ratio of the luminance, L, of a projected surface to the normal illuminance, $E_\perp$, at the surface on a plane normal to the incident light, expressed in candelas per square metre per lux ($cd \cdot m^{-2} \cdot lx^{-1}$).

3.2.1.1 *Discussion*—Because of the low luminance of pavement markings, the units used commonly are millicandelas per square metre per lux ($mcd \cdot m^{-2} \cdot lx^{-1}$).

3.2.2 *co-entrance angle, β_C, n*—the complement of the entrance angle ($90° - \beta$).

3.2.3 *co-viewing angle, v_C, n*—the complement of the viewing angle ($90° - v$).

3.2.4 *entrance angle, β, n*—the angle between the illumination axis and the retroreflector axis.

3.2.5 *observation angle, α, n*—the angle between the illumination axis and the observation axis.

3.2.6 *portable retroreflectometer, n*—a hand-held instrument that can be used in the field or laboratory for measurement of retroreflectance.

3.2.6.1 *Discussion*—In this test method, "portable retroreflectometer" refers to a hand-held instrument that can be placed over roadway delineation to measure the coefficient of retroreflected luminance with a prescribed geometry.

3.2.7 *presentation angle, γ, n*—the angle between the observation half-plane and the half-plane that originates on the illumination axis and that contains the retroreflector axis.

3.2.8 *instrument standard, n*—working standard used to standardize the portable retroreflectometer.

3.2.9 *retroreflection, n*—a reflection in which the reflected rays are returned preferentially in directions close to the opposite of the direction of the incident rays, this property

[1] This test method is under the jurisdiction of ASTM Committee E-12 on Appearance and is the direct responsibility of Subcommittee E12.10 on Retroreflection.

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

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

being maintained over wide variations of the direction of the incident rays.

3.2.10 *viewing angle, n*—the angle between the retroreflector axis and the observation axis.

3.2.10.1 *Discussion*—The retroreflector axis for pavement markings is normal to the marking.

4. Summary of Test Method

4.1 This test method involves the use of commercial portable retroreflectometers for determining the coefficient of retroreflected luminance of horizontal coating materials used in pavement markings.

4.2 The entrance angle is fixed at 88.76° (co-entrance angle 1.24°).

4.3 The observation angle is fixed at 1.05°.

4.4 The presentation angle shall be 0°.

4.5 The portable retroreflectometers use either a built-in reference white for standardization or use an external panel of known coefficient of retroreflected luminance, or both.

4.6 The retroreflectometer is placed directly over the pavement marking to be measured, ensuring that the measurement area of the retroreflectometer fits within the width of the stripe, and the reading displayed by the retroreflectometer is recorded.

4.7 The retroreflectometer is then moved to other positions on the pavement marking, and the readings are recorded and averaged.

4.8 Readings shall be taken and averaged in each direction of traffic for a centerline.

5. Significance and Use

5.1 The quality of the stripe is determined by the coefficient of retroreflected luminance, R_L, and depends on the materials used, age, and wear pattern. These conditions shall be observed and noted by the user.

5.2 Under the same conditions of illumination and viewing, larger values of R_L correspond to higher levels of visual performance.

5.3 Retroreflectivity of pavement (road) markings degrade with traffic wear and require periodic measurement to ensure that sufficient line visibility is provided to drivers.

5.4 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 material measured.

5.5 As specified by CEN, the measurement geometry of the instrument is based on centerline markings, a viewing distance of 30 m, an eye height of 1.2 m, and a headlight mounting height of 0.65 m.

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

6. Apparatus

6.1 *Portable Retroreflectometer*:

6.1.1 The retroreflectometer shall be portable, with the capability of being placed on various horizontal pavement markings in different locations.

6.1.2 The retroreflectometer shall be constructed so that placement on the highway pavement markings will preclude any stray light from entering the measurement area of the instrument and affecting the reading.

6.1.3 For the convenience of the user, a marking shall be placed on the instrument to permit it to be aligned with the direction of traffic.

6.2 *Light Source Requirements*:

6.2.1 The projection optics shall be such that the distribution of the illuminance over the measurement area will be within 10 % of the average illuminance.

6.2.2 The aperture angle of the light source as determined from the center of the measurement area shall not be larger than a rectangle subtending 10 min of arc (0.17°) by 20 min of arc (0.33°).

6.2.2.1 Rectangle aperture dimensions are given with the first side parallel to the observation half plane.

NOTE 2—The maximum source aperture dimensions are in agreement with CEN EN 1436. There is experimental evidence that for this test method, using this maximum source aperture together with the maximum receiver aperture in 6.3.3 produces R_L measurements within 1.5 % of those using two 10-min circular apertures as specified in Test Method D 4061.

6.3 *Receiver Requirements*:

6.3.1 The receiver shall have sufficient sensitivity and range to accommodate coefficient of retroreflected luminance values expected in use, typically 1 to 2000 $mcd \cdot m^{-2} \cdot lx^{-1}$.

6.3.2 If the retroreflectometer is intended to be used for measurement of marking materials other than white, the combined spectral distribution of the light source and the spectral responsivity of the receiver shall match the combined spectral distribution of CIE Illuminant *A* and the $V(\lambda)$ spectral luminosity function according to the following criterion: For any choice of plano parallel colored absorptive filter mounted in front of a white retroreflective sample, the ratio of the R_L measured with the filter to the R_L measured without the filter shall be within 10 % of the Illuminant *A* luminous transmittance of an air-spaced pair of two such filters.

6.3.3 The aperture of the receiver as determined from the center of the measurement area shall not be larger than a square subtending 20 min of arc (0.33°) by 20 min of arc (0.33°).

NOTE 3—The maximum receiver aperture dimensions are in agreement with CEN EN 1436. There is experimental evidence that for this test method, using this maximum receiver aperture together with the maximum source aperture in 6.2.2 produces R_L measurements within 1.5 % of those using two 10-min circular apertures as specified in Test Method D 4061.

6.3.4 Instruments with annular apertures are not recommended for measuring pavement markings.

6.3.5 The combined stability of the output of the light source and receiver shall be such that readings will not change more than ± 1 % after 10 s when the retroreflectometer is in contact with the pavement marking and ready to measure.

6.3.6 The linearity of the retroreflectometer photometric scale over the range of readings expected shall be within 2 %. Correction factors may be used to ensure a linear response. A method for determining linearity is found in Annex A2 of Practice E 809.

6.4 *Measurement Geometry*:

6.4.1 The light source and receiver may be either at optical infinity or at a finite distance from the measurement area, and

they shall be separated from each other by a distance corresponding to an observation angle of 1.05 ± 0.02°.

6.4.2 The entrance angle of the retroreflectometer shall be 88.76° ± 0.02° with respect to the entrance aperture plane.

6.4.3 The presentation angle of the retroreflectometer shall be 0° and shall be stated in the instrument specifications.

6.4.4 See Fig. 1 for a diagram of the optics geometry.

7. Sampling

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

7.2 Recommendations concerning the number of readings and spacing will be made in a later revision of this test method.

8. Standardization

8.1 The retroreflectometer shall be standardized using an instrument standard consisting of a separate panel of marking material with a known and reproducible coefficient of retroreflected luminance measured at the same geometry as used in the portable retroreflectometer. The instrument standard shall be standardized in accordance with Test Method D 4061, with the datum mark indicated on the standard. The instrument standard panel(s) shall have a standardization value of the coefficient of retroreflected luminance, R_L, within the expected pavement marking range. The standardization values shall be maintained by checking against other standards or using Test Method D 4061 sufficiently often to ensure that no large uncertainties in the measurement can occur.

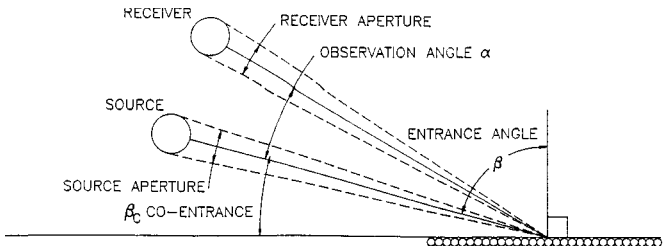

FIG. 1a Angles and apertures for non-collimating portable retroreflectometer

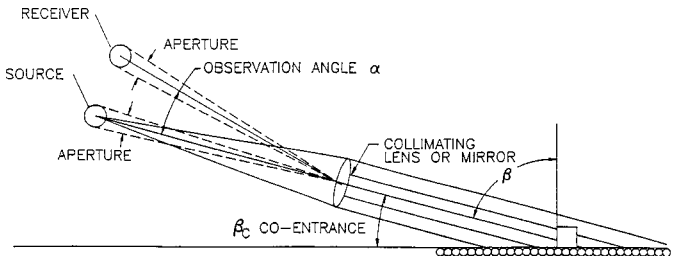

FIG. 1b Angles and apertures for collimating optics portable retroreflectometer

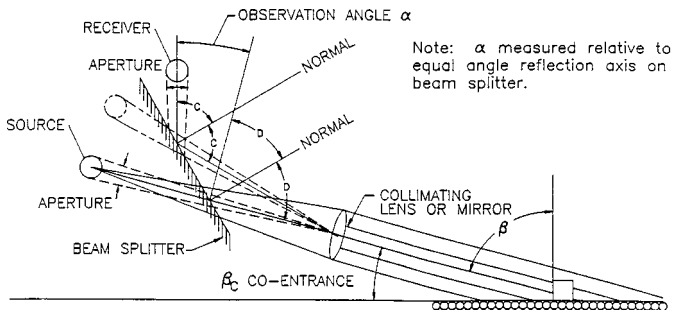

FIG. 1c Angles and apertures for portable retroreflectometer with collimating and beam splitter design

FIG. 1 Optics Geometry Diagram for Portable Road Marking Reflectometer: a) Angles and Apertures for Non-Collimating Portable Reflectometer; b) Angles and Apertures for Collimating Optics Portable Reflectometer; c) Angles and Apertures for Portable Reflectometer with Collimating and Beam Splitter Design

8.2 Subsequent to this standardization, an internal or secondary reference surface, either diffuse white or retroreflecting surface, may be used to maintain the standardization of the instrument during brief periods of transport to the test site area.

8.3 Note that transporting the instrument from an air conditioned area to the test site may result in fogging of mirrors (if any) in the instrument. If there is any doubt concerning the calibration or the readings are not constant, allow the instrument to reach ambient conditions and recalibrate with the instrument standard.

9. Procedure

9.1 Use the manufacturer's instructions for operation of the retroreflectometer, which generally uses the following procedure:

9.1.1 Ambient temperature shall be not less than 4°C (40°F).

9.1.2 The surface of the marking shall be clean and dry.

9.1.3 Turn on the retroreflectometer, and allow it to reach equilibrium following the manufacturer's instructions.

9.1.4 If the retroreflectometer has a zero-adjust control, set the display to 0 ± 2 in the least significant digit, with the instrument placed on a very black low retroreflectance panel.

9.1.5 If a standard panel is used, standardize the retroreflectometer by placing it on the instrument standard panel and setting the standardization control to the standardized value for that geometry.

9.1.6 For instruments with an internal reference surface, insert that surface into the light path and read the signal from the display. Record this reading.

9.1.7 Place the retroreflectometer squarely on the pavement marking material, ensuring that the measurement area of the retroreflectometer fits within the width of the stripe. The reading direction of the retroreflectometer shall be placed in the direction of traffic. Readings shall be taken for each direction of traffic and averaged separately for centerlines.

9.1.8 Record the retroreflectometer reading, and then move to other locations on the same sample set separated sufficiently to provide meaningful data (typically 1 metre), and record the results.

9.1.9 At intervals of one h or less, check the standardization and readjust the setting if the reading of either the internal standard or instrument standard has changed by more than 5 %.

10. Test Report

10.1 Include the following in the test report:

10.1.1 Test date.

10.1.2 Average of the readings at each test location, expressed as millicandelas per square metre per lux ($mcd \cdot m^{-2} \cdot lx^{-1}$). The average of the readings shall be reported for each traffic direction for centerlines.

10.1.3 Geographical location of the test site, including distance from the nearest permanent site identification, such as a mileage marker or crossroad.

10.1.4 Identification of the pavement marking material tested: type, color, age, and transverse location on road (edge line, first line, second line, and center).

10.1.5 Identification of the instrument used.

10.1.6 Value and date of standardization of the instrument standard panel used.

10.1.7 Entrance, viewing, and observation angles used to obtain the readings.

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

10.1.9 Ambient temperature.

11. Sources of Error

11.1 There are many factors that cause high variability when taking readings in the field. Some of these are as follows:

11.1.1 Slight changes in the position of the retroreflectometer on the traffic line may yield different readings.

11.1.2 Transverse lines may yield less uniform readings than longitudinal lines. Transverse lines have high wear in the wheel track area and less wear in the non-wheel track area.

11.1.3 The refractive index of the glass spheres and their depth of embedment as well as population on the pavement marking material will affect the readings.

11.1.4 The pigment loading of the binder, road films, dirt, salt, dust, water, etc. will also affect the readings.

11.1.5 The entrance angle with respect to the specimen plane will be affected by the physical characteristics of the specimen.

12. Precision and Bias

12.1 These data are under development.

13. Keywords

13.1 pavement markings; portable retroreflectometers; retroreflection