Designation: D7585/D7585M – 10 (Reapproved 2015)

Standard Practice for Evaluating Retroreflective Pavement Markings Using Portable Hand-Operated Instruments[1]

This standard is issued under the fixed designation D7585/D7585M; 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 practice describes several field techniques to evaluate the retroreflective properties of pavement markings containing retroreflecting optics (for example, centerlines and edgelines) and applied to the road surface. The techniques described in this practice contain sampling criteria such as the length of test sections and the number of measurements needed. The practice is based on retroreflective measurements made with portable hand-operated instruments in compliance with Test Method E1710.

1.2 The data obtained from this practice can be used to determine the acceptance or rejection of a project based on specified levels of retroreflectivity established by the agency having jurisdiction.

1.3 This practice can be used for the evaluation of newly installed or existing pavement markings. When testing newly applied pavement markings, it is recommended that the evaluation be done no sooner than 48 hours after application but before 30 days after application so that excess retroreflective optics, such as glass spheres, are no longer present.

1.4 The assessment techniques in this practice are based on best practices and designed to provide three levels of confidence in terms of quantifying the retroreflective performance of markings. Each technique represents a tradeoff between the number of measurements and the confidence of the retroreflective performance of the markings under study.

1.5 This practice can be used by agencies as is or may be customized to meet an agency's specific needs. Where applicable, the practice describes areas where different assumptions could be made, which would impact the sampling needs and the confidence levels of the results. When deviations from this practice are made, they shall be documented in the test report.

NOTE 1—When measuring newly installed pavement markings, there are several factors that contribute to erroneous values for measurements made within a short time after application, such as excess retroreflective optics, top-coatings on tape, incomplete curing of the binder, and coatings on the retroreflective optics. Retroreflective measurements taken within 48 h after application may be useful to quickly gauge the application quality but are not intended to be used with this practice.

NOTE 2—When measuring existing or in-service pavement markings, care should be taken so that representative sections of pavement markings are measured. There are particular conditions where excessive pavement marking wear can be associated with a specific cause such as vehicle tracking along horizontal curves, access points to gravel pits, and high weave areas. Pavement markings can also collect dirt, grime, and debris.

1.6 This practice replaces Test Method D6359 with a multi-level strategy for evaluating the retroreflectance of pavement marking materials. This change was desired to provide agencies with options for project acceptance and monitoring of pavement markings during service.

1.7 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

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:*[2]

D4061 Test Method for Retroreflectance of Horizontal Coatings

D6359 Specification for Minimum Retroreflectance of Newly Applied Pavement Marking Using Portable Hand-Operated Instruments (Withdrawn 2006)[3]

E284 Terminology of Appearance

[1] This practice is under the jurisdiction of ASTM Committee D04 on Road and Paving Materials and is the direct responsibility of Subcommittee D04.38 on Highway Traffic Control Materials.

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

E808 Practice for Describing Retroreflection
E1710 Test Method for Measurement of Retroreflective Pavement Marking Materials with CEN-Prescribed Geometry Using a Portable Retroreflectometer

3. Terminology

3.1 The terms and definitions in Terminology E284 and Practice E808 are applicable to this specification.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *acceptable quality level, AQL, n*—the maximum percent defective that, for purposes of sampling inspection, can be considered satisfactory as a process average (that is, the percent defective that can be tolerated without impairing performance).

3.2.1.1 *Discussion*—This is the maximum allowable proportion of pavement marking readings with values below specification.

3.2.2 *evaluation section*—the specific area of the pavement marking along which measurements will be made.

3.2.3 *limit quality, LQ, n*—limit of the AQL that is acceptable, providing a specified limited quality for protection.

3.2.3.1 *Discussion*—This is the proportion of pavement marking readings with values below the acceptable level, which in the worst case, would be allowed.

3.2.4 *producer's risk*—the risk the producer of the marking takes that the marking will fail the requirement specified when the marking is actually acceptable.

3.2.4.1 *Discussion*—If the population of the entire pavement marking fulfills the specification, there is still the probability that the sampling of the marking will fall below the required level as specified. This is designated the α risk (alpha risk).

3.2.5 *user's risk*—the risk the owner of the marking takes that the marking will meet the requirement specified when the marking retroreflectivity is actually substandard.

3.2.5.1 *Discussion*—If the population of the entire pavement marking fails the specification, there is still the probability that the sampling of the marking will equal or exceed the required level as specified. This is designated the β risk (beta risk).

4. Summary of Practice

4.1 This practice does not set the minimum retroreflectance values for newly installed pavement markings or minimum maintenance levels of pavement markings. It is the responsibility of the agency having jurisdiction to set the acceptable retroreflectivity values within their specifications.

4.2 This practice describes assessment techniques (including sampling criteria) to evaluate the retroreflective performance of pavement markings, which can then be used to determine compliance to a referenced specification. More specifically, this practice includes:

4.2.1 A nighttime visual inspection protocol to inspect the appearance of the markings and identify sections that appear to have inadequate retroreflectivity levels.

4.2.2 A standard evaluation protocol, which provides a reasonable measure of assurance that the retroreflectivity data collected with hand-held devices is representative of the markings being evaluated. The protocol was designed to require a minimum number of measurements while maintaining confidence with the results.

4.2.3 A more rigorous evaluation protocol, which provides a higher level of assurance that the retroreflectivity data collected with hand-held devices is representative of the marking being evaluated. This protocol requires an intensive measurement protocol and should be used as the referee method to resolve disputes regarding the status of a marking.

4.3 The three assessment techniques described in 4.2 were designed so that they could be used independently of one another. In other words, an agency can specify the use of a specific assessment technique, a combination, or all three. Furthermore, they are not meant to be used sequentially for all evaluations, but that is certainly an option.

5. Significance and Use

5.1 This practice provides procedures for the determination of the retroreflective performance of pavement markings. This practice does not set the minimum retroreflectance values for pavement markings, it describes sampling criteria for determining the retroreflective properties of pavement markings, which then can be used to determine compliance with a specification. It is the responsibility of the agency having jurisdiction to set the acceptable retroreflectivity values within their own specifications.

5.2 This practice does not purport to address all the concerns regarding contamination of the markings, but the following may be helpful. It is very important that the markings being evaluated are *clean and dry*. If the evaluation is being used relative to a measure of the performance of a contractor, it is imperative that the parties agree beforehand on the definition of *clean and dry*. There are many forms of contamination on a roadway that will lower the retroreflectivity readings of a marking, but not all of them can be removed. Asphalt oil and rubber skid marks are examples. Loose dirt can be removed by pressure washing, perhaps using soap, brushing or high-pressure air, however, these techniques are usually insufficient to remove dirt that is packed into the marking surface. Care should be taken to select areas that are *typical* of the marking section, avoiding areas of paint tracking or contamination, for example. It may be useful to take photographs using a digital camera and a good macro lens to be able to see the contamination on or between the glass beads.

6. Procedure

6.1 *Standardization of Portable Hand-Operated Retroreflective Measurement Instruments:*

6.1.1 Before taking measurements, the retroreflectometer(s) shall be standardized with an instrument standard as defined in Test Method D4061.

6.1.2 When more than one instrument is used, the instruments should be compared to a known standard in order to determine the characteristics of the specific instrument. These characteristics should be noted and taken into account when recording values.

6.2 *Nighttime Visual Inspection Protocol:*

6.2.1 This technique may be used to assess newly installed markings, and to assess the performance of in-service markings. This technique may be used to assess all types of pavement markings.

6.2.2 Schedule a night to conduct the visual inspection of the project so that the pavement markings are dry and the ambient weather conditions are free of rain, fog, or other types of precipitation.

6.2.3 A representative automobile or light passenger truck shall be used for the inspection. The headlamps shall be in good working condition and aimed correctly.

6.2.4 The inspection shall be conducted in full nighttime conditions (after civil twilight) with the vehicle headlamps on low beam.

6.2.5 Inspect all the markings visually through the windshield while driving at the posted speed.

6.2.6 Look for areas that appear to lack the luminance expected based on the specified retroreflectivity or lack the expected uniformity. Look for inconsistent areas where the luminance is below what could be expected for the pavement marking system being inspected. The use of an inspection panel with a known retroreflective level, which provides a known luminance level under given observation conditions, may be useful to identify inadequate sections. When conducting inspections of in-service markings (not newly applied markings), it is helpful to use multiple inspectors with expertise in pavement marking retroreflectivity.

6.2.7 If suspect areas are identified, note the locations. During a subsequent daytime inspection, ensure that the markings are representative and without excessive wear caused by such factors as a nearby gravel pit or in proximity to a high weave area. Evaluate the suspect areas in accordance with 6.3 Standard Evaluation Protocol or 6.4 Referee Evaluation Protocol to determine compliance to the required specification.

6.2.8 If no suspect areas are identified, record a minimum of four measurements and calculate the average. The averaged retroreflectivity level shall be used to determine compliance with the appropriate specification.

6.3 *Standard Evaluation Protocol:*

6.3.1 This technique is intended for longitudinal markings such as edgelines, lane lines, and centerlines. It is not intended to be used for pavement marking symbols, intersection markings, crosswalks, or other non-longitudinal pavement markings. Use 6.2 or 6.4 to evaluate the retroreflectivity of non-longitudinal pavement markings.

6.3.2 All measurements shall be made in the direction of travel. On the centerline of undivided highways, measurements shall be made in both directions unless otherwise specified by the agency having jurisdiction.

6.3.3 The evaluation sections can be obtained through the Nighttime Visual Inspection Protocol described in 6.2 (areas identified as being suspect). The evaluation sections can also be defined by the agency having jurisdiction, particularly if the Nighttime Visual Inspection Protocol described in 6.2 is not used.

6.3.4 The evaluation sections should be at least 400 ft [125 m] and clearly identified. There should be at least 3 evaluation sections per pavement marking of interest (unless the pavement marking of interest is less than 2 miles [3 km], in which case a minimum of one evaluation section is needed). For pavement marking lines longer than 10 miles [16 km] , the agency having jurisdiction may elect to specify more than three evaluation sections (such as three evaluation sections per 10 miles [16 km]). Measurements should be taken at regular intervals throughout the evaluation section. For lane lines and broken centerlines, two measurements should be taken on each skip line.

6.3.5 Once safe conditions are provided, portable hand-operated retroreflective measurements can be taken for each evaluation section. The intent is to take enough measurements to be confident that the mean of the measurements are close to the true mean retroreflectivity of the measurement section while minimizing the number of measurements needed. The recommended number of measurements is 16 per section, as described in Annex A1.

6.3.6 Once the measurements are recorded, calculate the average to determine a single retroreflectivity value representative for the evaluation section. This average value represents the retroreflectivity of the pavement marking and can be used to determine compliance with the appropriate specification. On the centerline of undivided roadways, the owner shall specify if the directional measurements will be averaged together to determine compliance with the appropriate specification or if they will be kept separate to determine compliance as a function of direction of travel.

6.4 *Referee Evaluation Protocol:*

6.4.1 This technique may be used to assess newly installed markings, and to assess the performance of in-service markings. This technique can be used to assess all types of pavement markings. The basis of this protocol is described in further detail in Annex A2.

6.4.2 All measurements are to be made in the direction of travel. On the centerline of undivided highways, measurements should be made in both directions unless otherwise specified by the agency having jurisdiction. Both single and double lines can be measured, the acceptance criteria of 6.4.5 shall be followed for each line.

6.4.3 *Longitudinal Pavement Marking Lines:*

6.4.3.1 *For Pavement Marking Lines 2 miles [3 km] or less (see* Fig. 1*)*—Measurements shall be made at one randomly located and representative evaluation section within the pavement marking line of interest. The sample size shall be set at 20 and assessed using the acceptance criteria of 6.4.5.

6.4.3.2 *For Pavement Marking Lines 2 to 10 miles [3 to 16 km] (see* Fig. 2*)*—Measurements shall be made at three randomly located and representative evaluation sections within the pavement marking line of interest. The evaluation sections shall not overlap. Measurements within each evaluation section shall be made with a sample size of 20 and assessed using the acceptance criteria of 6.4.5.

6.4.3.3 *For Pavement Marking Lines more than 10 miles [16 km]*—For assessing pavement marking lines longer than 10 miles [16 km], the agency having jurisdiction may elect to specify more than three evaluation sections (such as three evaluation sections per 10 miles [16 km]).

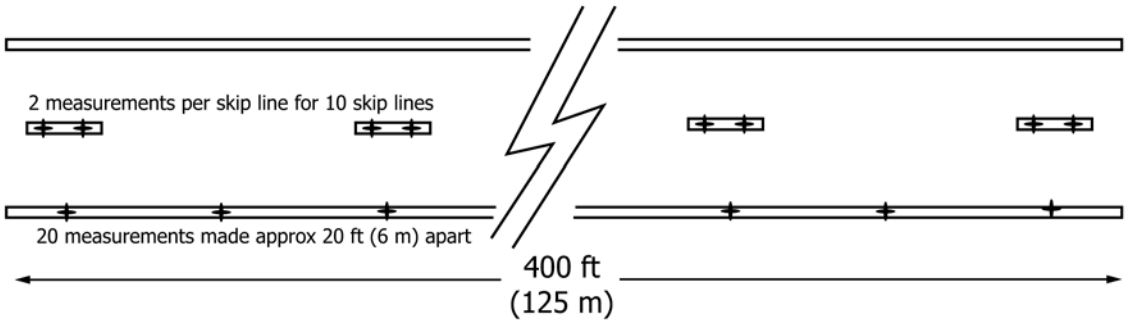

FIG. 1 Typical Referee Evaluation Section Randomly Located within Pavement Marking Test Section Less than 2 miles [< 3 km]

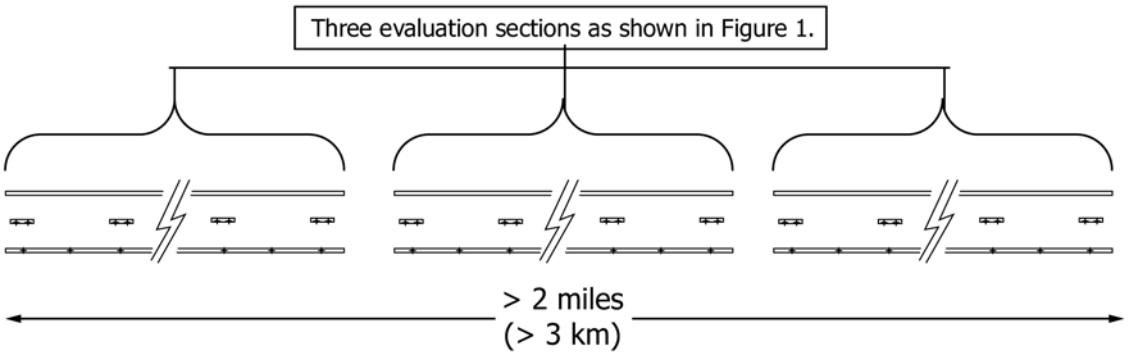

FIG. 2 Typical Referee Evaluation Section Randomly Located within Pavement Marking Test Section More than 2 Miles [> 3 km]

6.4.4 *Legends, Symbols, Pedestrian Crossing, and other Non-Longitudinal Markings:*

6.4.4.1 *Legends*—Each letter is considered as an evaluation section, and three (3) measurements shall be made in each letter in the direction of travel. The average value shall be calculated for each letter and used with the acceptance criteria described in 6.4.5.

6.4.4.2 *Symbols or Transverse Lines*—Each symbol or transverse line is considered a separate evaluation section. Six (6) measurements shall be made on symbols or transverse lines that are 8 ft [2.4 m] tall or wide. Three (3) measurements on symbols or transverse lines smaller than 8 ft [2.4 m] shall be made. The average value shall be calculated for each symbol or transverse marking and used with the acceptance criteria described in 6.4.5.

6.4.4.3 *Continental Style Pedestrian Crossings*—Three (3) random stripes shall be selected as an evaluation section. Six (6) measurements shall be made in each of the selected stripes. The average value of each stripe shall be calculated and used with the acceptance criteria described in 6.4.5.

NOTE 3—This practice does not establish where non-longitudinal markings are to be measured. Agencies should establish where the measurements are to be made with regards to the vehicle wheel paths, oil drippings, etc.

6.4.5 *Project Acceptance:*

6.4.5.1 For legends, symbols, pedestrian crossings, and other non-longitudinal markings, the average value of each measurement section can be used to compute the grand average. The grand average shall be used to determine compliance with the appropriate specification.

6.4.5.2 For longitudinal markings less than 2 miles [3 km], the average of the 20 measurements is used to determine the retroreflectivity of the marking. The averaged retroreflectivity level shall be used to determine compliance with the appropriate specification.

6.4.5.3 For longitudinal markings greater than 2 miles [3 km], the average retroreflectivity for each evaluation section shall be calculated. The grand average is determined using the average retroreflectivity from each evaluation section. The grand average shall be used to determine compliance with the appropriate specification.

NOTE 4—The standard deviation of the measurements can be used to assess the uniformity of the markings. A limitation of the exclusive use of the standard deviation, however, is that the magnitude of the mean of the measurements is not considered. Users can also use the coefficient of variation to further evaluate the uniformity of the markings while accounting for the mean of the markings. The coefficient of variation is defined as the ratio of the standard deviation to the mean. For a given mean value, it indicates a high or low degree of variability. For this reason, the coefficient of variation is useful when comparing dispersion of retroreflectivity measurements of pavement markings with different mean values. Agencies may choose to specify limits of variability using standard deviation or coefficient of variation.

7. Reporting

7.1 Include the following in the test report:

7.1.1 Test date and time,

7.1.2 Instrument operator name and contact information,

7.1.3 Pavement marking characteristics (for example, binder type, thickness, bead type, bead size), date of pavement marking installation if known, and other characteristics as specified,

7.1.4 Reference to appropriate specification of required minimum retroreflectivity level as established by the agency having jurisdiction,

7.1.5 The location of the measurements (for example, highway designation, mile points, direction of traffic, direction of material application, line identification, and other information as specified),

7.1.6 A description of the instrumentation and efforts to ensure it was calibrated properly during measurement periods,

7.1.7 If deviations are made from this practice, they shall be documented in the test report, and

7.1.8 The readings recorded in millicandelas per square meter per lux (mcd m^{-2} lx^{-1}).

8. Keywords

8.1 pavement markings; retroreflection

ANNEXES

(Mandatory Information)

A1. STANDARD EVALUATION PROTOCOL

A1.1 The statistical support for the recommended sample size of 16 measurements for the Standard Evaluation Protocol is provided in this annex. Depending on the assumptions used, other sample size estimates may be more appropriate and specified by the agency having jurisdiction.

A1.2 The following formula is used to determine the sample size (that is, the number of measurements) to estimate the true mean retroreflectivity of the measurement area to within an amount B with 95% confidence:

$$n = \left[\frac{196\sigma}{B}\right]^2 \quad \text{(A1.1)}$$

where B is the specified margin of error and σ is the true standard deviation of the handheld measurements. If B is unknown (which is usually the case in practice)[4], it can be estimated by the sample standard deviation from a preliminary study or a value from an educational guess (a somewhat larger value to be conservative). If B is specified in the unit of σ, for example, as B=σ/2, then

$$n = \left[\frac{196\sigma}{B}\right]^2 = \left[\frac{196\sigma}{\sigma/2}\right]^2 = [196 \times 2]^2 = 3.92^2 = 15.37 \cong 16 \quad \text{(A1.2)}$$

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A1.3 This ensures that with 95% confidence the estimated mean retroreflectivity based on the 16 handheld measurements will be no further than the half of the true standard deviation of the handheld measurements from the true mean retroreflectivity value of the evaluation section.

A1.4 It should also be noted that the recommendation of using a sample size of 16 measurements, along with recommendations provided in 6.3.4 regarding the spacing for the measurements, yields the recommendation in 6.3.4 of an approximately 400- ft [125 m] long evaluation section.

A1.5 For those wanting to have less of a margin of error or fewer required measurements (while willing to sacrifice on the error rate), the following sample sizes of handheld measurements are needed to estimate the true mean retroreflectivity value of the evaluation section to within B (with 95% confidence)

B	*n*
σ	4
σ/2	16
σ/3	35
σ/4	62
σ/10	385

A1.6 To this point, the statistical testing has been designed for two-tailed testing. If one is always testing against a specified threshold level (such as a minimum retroreflectivity for newly installed markings or a minimum performance retroreflectivity level to be met at some point in the future), and willing to accept that all measurements but particularly those on the very high side of the sample mean and substantially above the specified level be treated simply as non-significant, then one-tailed testing assumptions can be used, which result in fewer measurements needed per evaluation section. In that case, the sample size is chosen to ensure that the estimated mean retroreflectivity based on n measurements is no smaller than B below (or "no larger than B above" depending on whether the test is upper-tailed or lower-tailed) the true mean retroreflectivity. The one-tailed test statistic for the conditions described above is 1.645, which result in the following sample size recommendations.

B	*n*
σ	3
σ/2	11
σ/3	25
σ/4	44
σ/10	274

[4] Even after measurements are made, only a sample standard deviation is available, which is an estimate of the true standard deviation

A2. REFEREE EVALUATION PROTOCOL

A2.1 Use of the sampling procedure and tables for inspection by attributes forms the basis of the acceptance criteria described in 6.4, *Referee Evaluation Protocol*. For additional clarification, AQL is the percent defective for which the probability of acceptance is 1- α. Further, it should be noted that LQ is the percent defective for which the probability of acceptance is β. Thus, a sampling plan for which p(acceptance) = 1- α when percent defective = p_1 = AQL and p(acceptance) = β when percent defective = p_2 = LQ is required. In other words, if the measurements show that the pavement markings are acceptable, the probability is 95 percent that less than 6.5 percent of the pavement markings will be less than the level required by the agency with jurisdiction. If the testing shows that the markings are not acceptable, then the probability is 90 percent that more than 20 percent of the pavement markings have retroreflectivity levels less than those required. For this specification, the AQL is set at 6.5 percent and the LQ is set at 20 percent. The risks α and β should be based upon the engineering consequences of the pavement marking's failure to meet required retroreflectivity as specified by the agency with jurisdiction. For products whose failure to meet specifications does not result in loss of life or other catastrophic loss of performance, α and β levels that have traditionally been found acceptable are 0.05 and 0.1, respectively.