



# Standard Specification for Plowable, Raised Retroreflective Pavement Markers<sup>1</sup>

This standard is issued under the fixed designation D4383; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification covers a type of plowable, retroreflective, raised pavement marker for lane marking and delineation.

1.2 Retroreflective markers are intended for nighttime visibility.

1.3 The values stated in inch-pound units are to be regarded as the standard except where noted in the document. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.4 The following precautionary caveat pertains only to the test methods portion, Section 10, of this specification: *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*:<sup>2</sup>

[A536](#) Specification for Ductile Iron Castings

[C184](#) Test Method for Fineness of Hydraulic Cement by the 150- $\mu\text{m}$  (No. 100) and 75- $\mu\text{m}$  (No. 200) Sieves (Withdrawn 2002)<sup>3</sup>

[C430](#) Test Method for Fineness of Hydraulic Cement by the 45- $\mu\text{m}$  (No. 325) Sieve

[D5](#) Test Method for Penetration of Bituminous Materials

[D36](#) Test Method for Softening Point of Bitumen (Ring-and-Ball Apparatus)

[D70](#) Test Method for Density of Semi-Solid Bituminous Materials (Pycnometer Method)

[D71](#) Test Method for Relative Density of Solid Pitch and Asphalt (Displacement Method)

[D92](#) Test Method for Flash and Fire Points by Cleveland Open Cup Tester

[D113](#) Test Method for Ductility of Bituminous Materials

[D1754](#) Test Method for Effects of Heat and Air on Asphaltic Materials (Thin-Film Oven Test)

[D1785](#) Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120

[D1856](#) Test Method for Recovery of Asphalt From Solution by Abson Method

[D2171](#) Test Method for Viscosity of Asphalts by Vacuum Capillary Viscometer

[D2172](#) Test Methods for Quantitative Extraction of Bitumen From Bituminous Paving Mixtures

[D2669](#) Test Method for Apparent Viscosity of Petroleum Waxes Compounded with Additives (Hot Melts)

[D4280](#) Specification for Extended Life Type, Nonplowable, Raised Retroreflective Pavement Markers

[D3111](#) Test Method for Flexibility Determination of Hot-Melt Adhesives by Mandrel Bend Test Method

[D4402](#) Test Method for Viscosity Determination of Asphalt at Elevated Temperatures Using a Rotational Viscometer

[D5329](#) Test Methods for Sealants and Fillers, Hot-Applied, for Joints and Cracks in Asphaltic and Portland Cement Concrete Pavements

[E18](#) Test Methods for Rockwell Hardness of Metallic Materials

[E284](#) Terminology of Appearance

[E308](#) Practice for Computing the Colors of Objects by Using the CIE System

[E691](#) Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

[E808](#) Practice for Describing Retroreflection

[E809](#) Practice for Measuring Photometric Characteristics of Retroreflectors

<sup>1</sup> This specification 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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<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

<sup>3</sup> The last approved version of this historical standard is referenced on [www.astm.org](http://www.astm.org).

**E811 Practice for Measuring Colorimetric Characteristics of Retroreflectors Under Nighttime Conditions**

2.2 *Federal Specifications*:<sup>4</sup>

**TT-T-291 Thinner, Paint, Mineral Spirits, Regular and Odorless**

2.3 *AASHTO Standards*:<sup>5</sup>

**AASHTO M237 Epoxy Resin Adhesive for Bonding Traffic Markers to Hardened Concrete**

**3. Terminology**

3.1 *Definitions*:

3.1.1 *cleanability*—the ability of a raised retroreflective marker to keep its optical surfaces clean under traffic and environmental conditions.

3.1.2 *coefficient of luminous intensity*,  $R_l$ —the ratio of the luminous intensity ( $I$ ) of the retroreflector in the direction of observation to the illuminance ( $E$ ) at the retroreflector on a plane perpendicular to the direction of the incident light, expressed in candelas per lux (cd/lx) (see Practice **E808** and Terminology **E284**).

3.1.2.1 *Discussion*—The values presented for the coefficient of luminous intensity are presented in SI units, which are the accepted worldwide norm for expressing this value, rather than in inch-pounds. When values are low, the coefficient of (retroreflected) luminous intensity may be given in millicandelas per lux. In inch-pound units,  $R_l$  is given in candelas per footcandle (cd/ftc). Historically, the term “specific intensity” and symbol “SI” have been used to designate this term but “ $R_l$ ” is preferred.

3.1.3 *color*—expressed by chromaticity coordinates according to the CIE (Commission Internationale de l’Eclairage 1931) standard colorimetric system.

3.1.4 *horizontal entrance angle*—the angle in the horizontal plane between the direction of incident light and the normal to the leading edge of the marker.

3.1.4.1 *Discussion*—This angle corresponds to the entrance angle component  $\beta_2$  when the marker is positioned for photometry. (See Practice **E808**.) The direction given in Practice **E808** should be used when designating this angle.

3.1.5 *observation angle*—the angle at the reflector between the illumination axis and the observation axis. (See Practice **E808**.)

3.2 *Definitions of Terms Specific to This Standard*:

3.2.1 *raised retroreflective pavement markers, raised retroreflective marker, retroreflective marker, and marker*—used interchangeably in this specification to refer to a molded plastic prismatic retroreflector, the reflecting area of which is covered with an abrasion-resistant lens surface. The terms do not include the metal holder sometimes used to protect markers from plow blades.

<sup>4</sup> Available from U.S. Government Printing Office Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401, <http://www.access.gpo.gov>.

<sup>5</sup> Available from American Association of State Highway and Transportation Officials (AASHTO), 444 N. Capitol St., NW, Suite 249, Washington, DC 20001, <http://www.transportation.org>.

**4. Classification**

4.1 Markers shall be classified as to type, color, and intended application.

4.1.1 *Types of Markers*:

4.1.1.1 *Type A*—Two-way retroreflective markers, one color.

4.1.1.2 *Type B*—One-way retroreflective markers, one color.

4.1.1.3 *Type E*—Two-way retroreflective marker, two colors.

4.1.2 *Color of Markers*:

4.1.2.1 *W*—White,

4.1.2.2 *Y*—Yellow,

4.1.2.3 *R*—Red,

4.1.2.4 *B*—Blue, and

4.1.2.5 *G*—Green.

4.1.3 *Intended Application of Markers*:

4.1.3.1 Marker to be mounted in a holder.

4.1.3.2 Marker to be mounted in a recess.

4.1.4 Show classification in the order detailed in **4.1.1 – 4.1.3.2**: type, color, and application.

4.2 Holders shall be classified as to the design installed height of the holder above the pavement.

**5. Ordering Information**

5.1 Orders for markers under this specification should include the following information:

5.1.1 Quantity,

5.1.2 Type of marker—Retroreflective one-way or retroreflective two-way, and

5.1.3 Color of marker.

5.2 Orders for holders under this specification should include the following information:

5.2.1 Design installed maximum height of the holder.

**6. Performance Requirements**

6.1 *Retroreflectivity*

6.1.1 For new markers, coefficient of luminous intensity (RI) measured in accordance with **10.1** shall be not less than the values in **Table 1**.

**TABLE 1 Coefficient of Luminous Intensity  $R_l$**

NOTE 1—The retroreflector axis and datum axis of the marker are as shown in **Fig. 2** and **Fig. 3**.

NOTE 2—Entrance angle component  $\beta_1$  and rotation angle  $\epsilon$  are  $0^\circ$ .

NOTE 3—The values presented for the coefficient of luminous intensity in the table are given in SI units, which are the accepted worldwide norm for expressing this value, rather than in inch-pounds. The values in *cd/ftc* are provided for information.

Entrance Angle $\beta_2$	Observation Angle $\alpha$	Minimum Value $R_l$ , <i>mcd/lx</i>				
		White	Yellow	Red	Green	Blue
$0^\circ$	$0.2^\circ$	279	167	70	93	26
$+20^\circ/-20^\circ$	$0.2^\circ$	112	67	28	37	10
Entrance Angle $\beta_2$	Observation Angle $\alpha$	Minimum Value $R_l$ , <i>cd/ftc</i>				
		White	Yellow	Red	Green	Blue
$0^\circ$	$0.2^\circ$	3.0	1.8	0.75	1.0	0.28
$+20^\circ/-20^\circ$	$0.2^\circ$	1.2	0.72	0.30	0.40	0.11

6.1.2 After abrading the marker per 10.2, coefficient of luminous intensity at 0° entrance angle measured in accordance with 10.1 shall be not less than the values in Table 1 multiplied by 0.5.

NOTE 1—No laboratory abrasion test has been established for markers having biconvex optical elements.

NOTE 2—Some two-color markers may intentionally have only one of the retroreflective faces abrasion resistant, in which case the second face should not be abraded.

NOTE 3—No laboratory abrasion test can be expected to model the full range of surface wear of pavement markers in use.

6.2 Color—When the retroreflector is illuminated by a CIE Standard Source A and when measured in accordance with 10.3, the color of the retroreflected light shall fall within the color gamuts given by the following corner points and shown in Fig. 1:

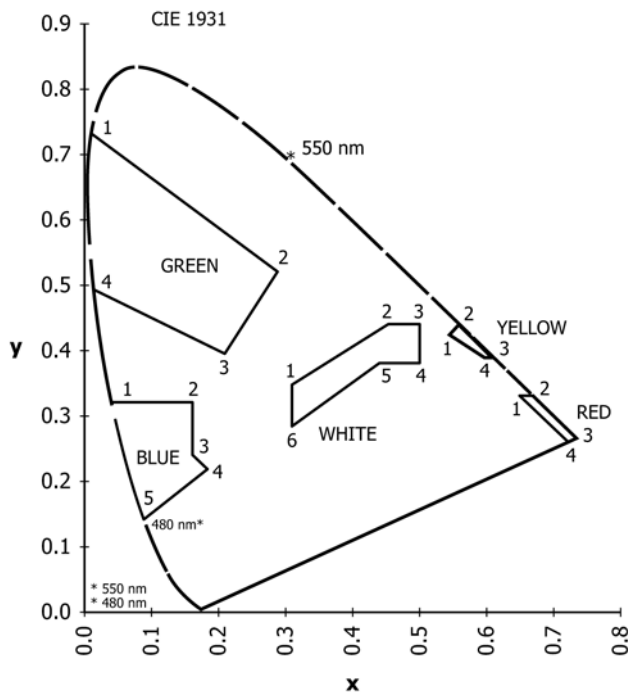


FIG. 1 Color Gamut per 6.2

6.2.1 White

Point No.	x	y
1	0.310	0.348
2	0.453	0.440
3	0.500	0.440
4	0.500	0.380
5	0.440	0.380
6	0.310	0.283

6.2.2 Yellow

Point No.	x	y
1	0.545	0.424
2	0.559	0.439
3	0.609	0.390
4	0.597	0.390

6.2.3 Red

Point No.	x	y
1	0.650	0.330
2	0.668	0.330
3	0.734	0.265
4	0.721	0.259

6.2.4 Blue

Point No.	x	y
1	0.039	0.320
2	0.160	0.320
3	0.160	0.240
4	0.183	0.218
5	0.088	0.142

6.2.5 Green

Point No.	x	y
1	0.009	0.733
2	0.288	0.520
3	0.209	0.395
4	0.012	0.494

6.3 Lens Impact Strength—When impacted in accordance with 10.4.2 the face of the lens shall show no more than two radial cracks longer than 0.25 in. (6.4 mm). There shall be no radial cracks extending to the edge of the abrasion-resistant area. There shall be no delamination.

6.4 Temperature Cycling—When subjected to temperature cycling in accordance with 10.4.3 there shall be no cracking or delamination.

6.5 Adhesive Bond Strength—Because no practical laboratory procedures have been determined to provide complete, reliable, and predictive information on adhesive bond strength, the user is encouraged to seek information from alternative sources such as field tests. A field test of duration 12 months is recommended. A control marker is chosen with known satisfactory adhesion. The test markers may be required to experience no more than 1.5 times as great an adhesion failure rate as the controls. The test severity should be such that between 3 % and 20 % of the controls fail during the field test. There must be adequate numbers of test markers and controls for statistical validity.

6.6 Compressive Strength—Tested in accordance with 10.5, a marker shall support a load of 6000 lbf (26700 N, 2720 kgf) without breakage or significant deformation of the marker. Significant permanent deformation shall be understood to be 0.13 in. (3.2 mm). For markers laminated to an elastomeric pad, remove the pad before testing.

6.7 Ramp Hardness of Holders—Measured in accordance with 10.6, the hardness of the ramps shall be 51-55 HRC.

7. Construction Requirements for Retroreflective Markers

7.1 To withstand plowing, raised retroreflective markers are protected either by recessing within a groove below the pavement surface (see Appendix X1), mounting within a holder having metal ramps to deflect plowblades, or by other methods approved by the purchaser.

7.2 Retroreflective Markers:

7.2.1 The marker shall be comprised of materials with adequate chemical, water, and UV resistance for the intended use.

7.2.2 The marker width shall be approximately 4 in. (102 mm).

7.2.3 The angle between the face of the marker and the base shall be no greater than 45°.

7.2.4 Markers to be mounted in a holder may preferably be laminated to an elastomeric pad.

7.2.5 The base of the marker shall be flat within 0.05 in. (1.3 mm). If the bottom of the marker is configurated, the outermost faces of the configurations shall not deviate more than 0.05 in. (1.3 mm) from a flat surface.

7.2.6 Other construction meeting the performance requirements will be acceptable following a six-month road test during the time of the year when weather and traffic conditions are most critical to determine cleanability and durability.

### 7.3 Holder:

7.3.1 The installed height of the holder shall not exceed 0.43 in. (10.9 mm) above the road surface.

7.3.2 The holder shall be nodular iron, conforming to Specification **A536**, Grade 80-55-06, hardened to 51-55 HRC, when tested according to Test Methods **E18**.

7.3.3 To minimize plow blade impact and damage to the casting, the plow blade deflecting ramps of the holder shall be angled not more than 6° to the surface of the road.

7.3.4 The ramps shall be so designed that there shall be no vertical surfaces above the road level that can be contacted by the plow blade moving in the normal travel direction of the road.

7.3.5 Surfaces of the holder shall be free of scale, dirt, rust, oil, grease, or any other contaminant which may reduce its bond to the adhesive with which the holder is installed or with which the marker is mounted.

7.3.6 The holder shall be designed to be partially recessed below the pavement surface to withstand plow impact. It shall have means for indexing the pavement surface, such as tabs.

7.3.7 Other holder constructions may be acceptable at the option of the purchaser following a six-month road test during the time of the year when weather conditions are most critical to determine durability.

## 8. Sampling

8.1 For markers supplied not mounted in holders, 26 markers selected at random will constitute a representative sample for each lot consisting of 10 000 markers or less. Forty markers will constitute a representative sample for lots consisting of more than 10 000 markers. The lot size shall not exceed 25 000 markers.

8.2 For markers supplied mounted in holders, the purchaser may require the sample quantities specified in **8.1** or, alternatively for practicality of testing, may require 10 samples of the markers installed in holders and, in addition, require that the manufacturer submit 26 or 40 loose markers, as in **8.1**, certified to be representative of the markers shipped in holders.

## 9. Number of Tests and Retests

9.1 For coefficient of luminous intensity before abrasion (**6.1**), the entire sample of retroreflective pavement markers shall be photometered in accordance with **10.1**. The failure of more than 10 % of the retroreflective faces shall be cause for rejection of the entire lot represented by the sample.

9.2 For abrasion resistance (**6.1.2**), four retroreflective faces passing the photometric requirements of **6.1** shall be subjected to abrasion in accordance with **10.2** and rephotometered in

accordance with **10.1**; the failure of more than one retroreflective face shall be cause for rejection of the entire lot.

9.3 For compressive strength (**6.6**), and color (**6.2**), three specimens shall be tested for each requirement. Specimens previously subjected to measurement of coefficient of luminous intensity before abrasion, **10.1**, measurement of abrasion resistance, **10.2**, and to color tests may be used for tests of compressive strength. Failure of more than one specimen shall be cause for rejection of the lot.

9.4 For lens impact strength (**6.3**), resistance to temperature cycling (**6.4**), and ramp hardness of holders (**6.7**), ten specimens shall be tested for each requirement. Failure of more than one of the specimens in any one test shall be cause for rejection of the entire lot.

9.5 In the event of failure that would result in rejection of a lot, and at the direction of the purchaser, a resample may be taken consisting of double the number of samples originally taken. Tolerances for resamples shall be in the same ratio as specified in **9.1** through **9.4**.

## 10. Test Methods

### 10.1 Coefficient of Luminous Intensity:

10.1.1 *Procedure*—Measure coefficient of luminous intensity in accordance with Practice **E809**. Angular aperture of the source and angular aperture of the receiver shall each be no larger than 0.1°. Angular aperture of the retroreflective elements shall be no larger than 0.02°. If the retroreflective elements are no larger than 0.21 in. (5.3 mm) diameter, suggested test dimensions are 50 ft (15.2 m) distance, 1.0 in. (25.4 mm) diameter receptor and 1.0 in. (25.4 mm) diameter source. Other test distances are acceptable provided that the stated angular aperture requirements are met and that the marker subtends no more than 1° at the source. Measure the distance from the light source exit pupil to the center of the retroreflective face of the marker. The base of the marker shall lie on a plane parallel to the illumination axis and perpendicular to the observation half-plane. Refer to **Figs. 2 and 3** and Practice **E809**. Any vertical surfaces on the marker, for example, on its leading edge, that could specularly reflect the source into the receiver shall be covered. The tolerance on entrance angle shall be  $\pm 0.5^\circ$ . Maintain laboratory and condition markers to  $73.4 \pm 3.6^\circ\text{F}$  ( $23 \pm 2^\circ\text{C}$ ),  $50 \pm 25\%$  RH.

10.1.2 If the markers are mounted in a holder photometer the markers in the holder, and if the holder shadows the retroreflective area divide the measured coefficient of luminous intensity by the ratio of the unshadowed retroreflective area to the total retroreflective area for comparison with **Table 1**.

10.1.3 Before photometry, gently wipe the face of the marker with a soft damp towel, then dry with a soft towel.

### 10.1.4 Interlaboratory Study of Precision

10.1.4.1 The calculations, results, and terminology used to prepare this statement follow Practice **E691**.

10.1.4.2 A set of markers conforming to this specification was photometered at six laboratories. The set comprised 150 lenses, equally divided among the five colors of section **6.2** and also equally divided among three optical types: those having prisms approximately 0.1 in. (2.5 mm) in diameter; those

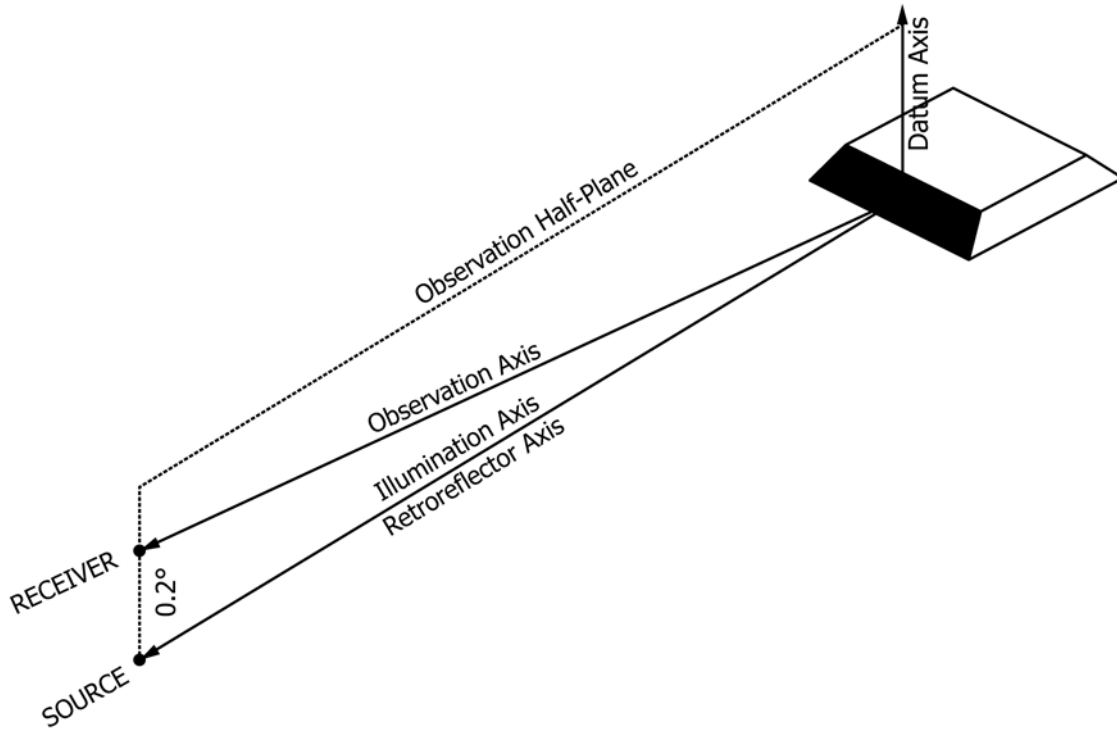


FIG. 2 Position of Marker for Photometry, 0° Entrance Angle

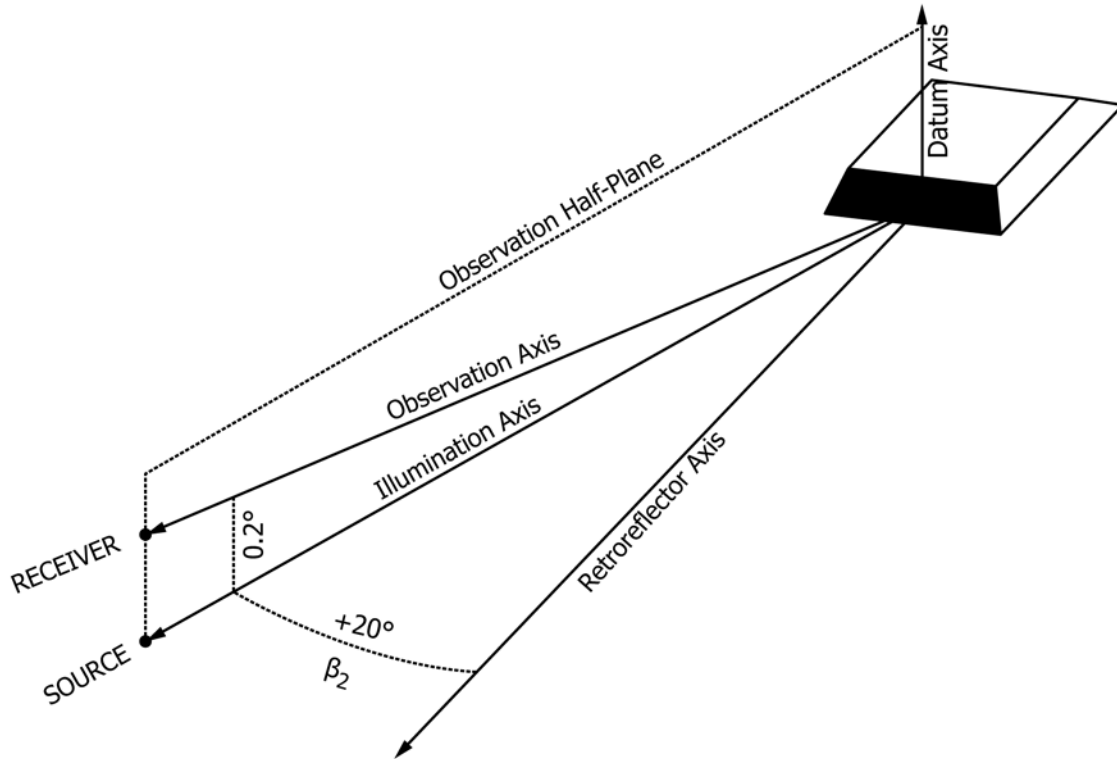


FIG. 3 Position of Marker for Photometry, +20° Entrance Angle

having prisms approximately 0.012 in. (0.3 mm) in diameter; and those having discrete biconvex elements.

NOTE 4—The sample markers met the dimensional requirements of

Specification D4280. The results of the interlaboratory study are applicable also to markers meeting the dimensional requirements of the present Specification.



10.1.4.3 Each laboratory photometered each lens at 0.2° observation angle at each of 0°, +20°, and -20° entrance angles in accordance with 10.1.1, and the measurements were repeated on a second day.

10.1.4.4 The precision statistics are given in Table 2. For each lens, precision statistics were calculated as percentages of the interlaboratory mean  $R_I$  value for that lens. The precision statistics were averaged over the 10 specimens of like color and optical type. The precision statistics for +20° entrance angle and for -20° entrance angle were averaged for the reported ±20° entrance angle. The differences in precision statistics among the five colors were small enough to allow average values to be reported. The differences in precision statistics among the three optical types were small enough to allow average values to be reported.

10.1.4.5 There is no estimate of bias. There is no reference laboratory in North America by which to establish bias for this measurement.

10.2 Abrasion Resistance

10.2.1 The abrasion resistance test method is only applicable to markers having a smooth continuous lens surface.

10.2.2 Sand shall fall 9.8 ± 0.1 ft (3.00 ± 0.03 m) uniformly onto the front of a marker having its retroreflector axis vertical. Distance shall be measured to the marker's leading edge.

10.2.3 Sand shall be natural silica sand from the St. Peters or Jordan sandstone deposits (located in the central United States).

10.2.3.1 This sand is characterized by its roundness of grains and its exceptionally high silicon dioxide content.

10.2.4 The sand particle distribution shall be such that not more than 10 % by weight is retained on a No. 20 (850 μm) sieve and not more than 10 % by weight passes a No. 30 (600 μm) sieve after 10 min of continuous sieving.

10.2.5 Sand shall not be reused.

10.2.6 Sand shall fall at least 9.4 ft (2.85 m) before reaching a calibration aperture, a horizontal rectangular opening 1.57 ± 0.04 in (4.0 ± 0.1 cm) by 4.72 ± 0.04 in (12.0 ± 0.1 cm), under which the marker is centered with the marker width in the 4.72 in (12 cm) direction.

10.2.7 A total of 2.5 ± 0.05 kg of sand shall fall through a calibration aperture at a rate maintained in the range from 0.4 kg/min to 1.0 kg/min.

10.2.8 The abrasion resistance test shall be performed at 25 ± 5°C and 50 ± 25 % RH with the markers pre-conditioned to those ranges.

10.2.9 Abrasion Apparatus

10.2.9.1 The apparatus shall consist of a vertical pipe with a sieve at the top, a calibration aperture with deflectors at the

bottom, a marker support, and a means for collecting the sand that passes through the calibration aperture.

10.2.9.2 Sand shall fall within the full unobstructed pipe from the sieve to the plane of the calibration aperture.

10.2.9.3 The pipe shall have inner diameter at least 5.9 in (15 cm). Smooth plastic pipe conforming to Specification D1785 may be used. The pipe shall be within 0.2° of vertical.

10.2.9.4 The sieve shall be used to establish the beginning point of the sand drop and also to limit sand flow. Sand may fall no more than 1.2 in (3 cm) onto the sieve.

NOTE 5—The sieve must be coarser than the sieves mentioned in 10.2.4.

10.2.9.5 The calibration aperture shall be formed from four sharp horizontal edges which are the upper edges of angled deflectors. See Fig. 4. Sand falling within the calibration aperture is not deflected; sand falling outside the calibration aperture is deflected away from the aperture and cannot strike the marker.

10.2.9.6 The marker shall be mounted with its leading edge no farther than 5.9 in (15 cm) from the plane of the calibration aperture. The marker shall be mounted with no fixturing within 1 cm of its front face. Fixturing must be such to allow free flow of sand around the marker. Plane of marker base shall be within 1° of vertical. Marker leading edge shall be within 2° of horizontal.

10.2.9.7 All sand passing through the calibration aperture, including any that bounces off the marker, must be collected and weighed. Sand that does not pass through the calibration aperture must not be included in this weight.

10.2.9.8 Sand must flow equally through all parts of the calibration aperture. This shall be verified by placing at least ten vials having approximately 0.4 in. (1 cm) mouths at the height of the marker under the aperture. When enough sand has dropped through the apparatus that at least one of the vials has received at least 0.2 oz. (5 g), the least filled vial shall have received at least 75 % as much weight of sand as the most filled vial. After determining the flow stability of the apparatus, verify uniformity as often as necessary.

10.2.10 Interlaboratory Study of Precision

10.2.10.1 The calculations, results, and terminology used to prepare this statement follow Practice E691 except for minor modifications to accommodate the unequal numbers of samples tested at the participating laboratories.

10.2.10.2 The measured quantity is the unitless ratio of the coefficient of luminous intensity ( $R_I$ ) at 0° entrance angle after abrasion to the coefficient of luminous intensity ( $R_I$ ) at 0° entrance angle before abrasion. The repeatability of the measurement therefore depends on both the repeatability of the  $R_I$  measurement and the repeatability of the abrasion. The reproducibility of the measurement depends primarily on the reproducibility of the abrasion.

10.2.10.3 The sample markers were of three types LPG, LPC, SPC, depending on their optics and front surface. LP denotes having prisms approximately 0.1 in (2.5 mm) in diameter and SP denotes having prisms approximately 0.01 in (0.3 mm) in diameter. G denotes glassed and C denotes coated. The markers of each type were as identical as practical manufacturing allowed. All reflectors were white.

TABLE 2 Precision for Coefficient of Luminous Intensity

Entrance Angle	$S_r$ Repeatability Standard Deviation	$S_R$ Reproducibility Standard Deviation	$r$ 95 % Repeatability Limit	$R$ 95 % Reproducibility Limit
0°	1.5 %	6.7 %	4.1 %	18.5 %
±20°	4.0 %	9.0 %	11.1 %	25.0 %

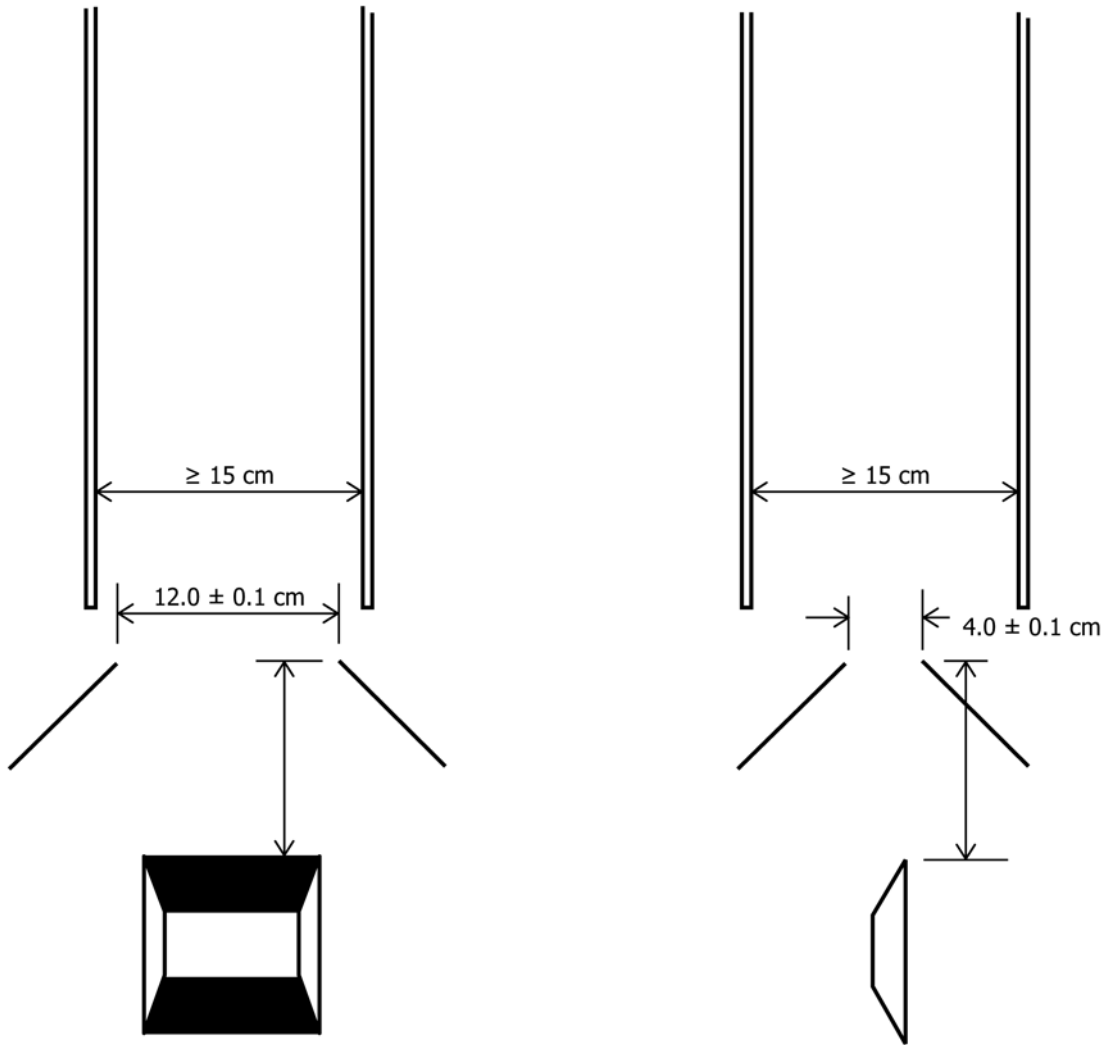


FIG. 4 Abrasion Resistance Test Apparatus

NOTE 6—The sample markers met the dimensional requirements of Specification D4280. The results of the interlaboratory study are applicable also to markers meeting the dimensional requirements of the present Specification.

10.2.10.4 The study included four laboratories. Each laboratory photometered, abraded, and re-photometered between 10 and 20 markers of each type. Markers were conditioned to within 3.6°F (2°C) for the pre-abrasion and post-abrasion photometry.

10.2.10.5 The precision statistics are given in Table 3.

10.2.10.6 The data given in Table 4 suggest upper limits to the contribution of manufacturing variation within the three types to the precision statistics.

10.2.10.7 There is no estimate of bias. No reference abrasion apparatus exists by which to establish bias in the abrasion. Any photometric bias is expected to nearly cancel in the ratioing.

10.3 Color—Measure color in accordance with Practice E811 at 0.2° observation angle and 0° entrance angle. The

TABLE 3 Precision for Abrasion Resistance

Marker Type	$\bar{X}$ Mean of Labs' Means	$S_x$ Standard Deviation of Laboratory Means	$S_r$ Repeatability Standard Deviation	$S_L$ Standard Deviation of Assumed Normal Distribution of Laboratory Means	$S_R$ Reproducibility Standard Deviation	$r$ 95 % Repeatability Limit	$R$ 95 % Reproducibility Limit
LPG	0.786	0.096	0.037	0.095	0.102	0.101	0.282
LPC	0.583	0.078	0.076	0.076	0.107	0.211	0.297
SPC	0.770	0.072	0.058	0.071	0.091	0.160	0.253

**TABLE 4 Sample Consistency for Abrasion Resistance**

Marker Type	Lowest of Labs' Standard Deviations	Number of Samples, <i>n</i> , at that lab
LPG	0.020	15
LPC	0.023	20
SPC	0.038	15

source and receptor angular aperture shall each be 6 min of arc. Calculate chromaticity coordinates in accordance with E308.

#### 10.4 Resistance to Lens Cracking

10.4.1 Separate markers laminated to an elastomeric pad from the pad before testing.

10.4.2 *Lens Impact Strength*—Condition the markers in a convection oven at 130°F (55°C) for 1 h.

10.4.2.1 While at the elevated temperature, impact the reflective face of the marker by allowing a 0.42-lb (190-g) dart fitted with a 0.25-in (6.4-mm) radius semispherical head to drop 18 in (457 mm) perpendicularly onto the approximate center of the reflective surface. For impact testing, set the marker on a steel fixture designed to hold the reflecting face horizontal, and place the fixture on a solid surface such as a concrete floor.

10.4.2.2 Inspect for cracking and delamination.

10.4.3 *Resistance to Temperature Cycling*—Subject samples to 3 cycles of 140°F (60°C) for 4 h followed by 20°F (–7°C) for 4 h.

10.4.3.1 Inspect for cracking and delamination.

10.4.4 *Precision and Bias*—No statement is made about either the precision or bias of the test for resistance to lens cracking since the result merely states whether there is conformance to the criteria for success specified in the procedure.

#### 10.5 Compressive Strength:

10.5.1 Condition markers at 73.4° ± 3.6°F (23.0° ± 2.0°C) for 4 h and separate markers laminated to an elastomeric pad from the pad prior to testing.

10.5.2 Position marker base down at the center of a 0.5-in. (13 mm) thick flat steel plate larger than the marker.

10.5.3 On top of the marker place a 0.375 in. (9.5 mm) thick elastomeric pad larger than the marker and having a shore A durometer of 60.

10.5.4 On top of the elastomeric pad place a 13 mm (0.5 in.) thick flat steel plate larger than the marker.

10.5.5 Apply a load at a rate of 0.1 in. (2.5 mm)/min until the specified load is reached.

#### 10.6 Holder Ramp Hardness Test:

10.6.1 Prepare spot for test on horizontal surface of ramp close to angled portion by using a hand grinder to remove only a slight amount of metal to smooth surface.

10.6.2 Place the holder in a Rockwell hardness tester with ramps facing upward, and position the holder on the flat anvil of the tester with the smooth area below the indenter.

10.6.3 Check hardness at three locations approximately 0.06 in. (1.5 mm) apart on smooth area, and average the three readings to obtain the hardness.

### 11. Packaging

11.1 Shipments shall be made in containers which are acceptable to common carriers and packaged in such a manner as to ensure delivery in perfect condition. Any damaged shipments shall be replaced by the contractor. Each package shall be clearly marked as to the name of the manufacturer, type, color, quantity enclosed, and date of manufacture.

### 12. Keywords

12.1 delineation; plowable markers; raised pavement markers; retroreflective markers

## ANNEX

### (Mandatory Information)

#### A1. SPECIFICATION FOR BITUMINOUS ADHESIVE FOR PAVEMENT MARKERS

##### A1.1 Scope

A1.1.1 This specification establishes the requirements for bituminous installation adhesive to be used for placement of recessed, raised, retroreflective pavement markers. The adhesive shall be suitable for bonding the above markers to portland cement concrete, asphaltic concrete, and chip sealed road surfaces and applicable when road surface and marker temperatures are in the range from 40 to 160°F (4.4 to 71°C). The adhesive properties will not deteriorate when heated the application temperature recommended by the manufacturer.

##### A1.2 Classification

A1.2.1 *Type I*—A hot-melt bituminous adhesive without polymer, fibers, or GTR (ground tire rubber) modification.

A1.2.2 *Type II*—A hot-melt flexible bituminous adhesive modified with polymer excluding GTR.

A1.2.3 *Type III*—A hot-melt flexible bituminous adhesive containing GTR.

##### A1.3 Adhesive Specifications

A1.3.1 The bituminous installation adhesive is an asphaltic material with a homogeneously mixed mineral filler. The adhesive shall not contain rubber polymers since necessary application temperatures cause decomposition, resulting in unsatisfactory performance. The adhesive shall conform to the following requirements:



Property	Test Method	Type I	Type II	Type III	Specific Gravity at 77°F (25°C)	D71	1.6 – 1.85	1.10 – 1.35	1.25 – 1.50
Softening point, °C (°F)	D36	200 – 264	200 (93) min (93 – 129)	200 (93) min					
Penetration at 77°F, 3.5 oz, 5s, in (25°C, 100 g, 5s, mm)	D5	0.04 – 0.070	0.12 (3) max (1 – 1.8)	0.12 (3) max					
Penetration at 140°F, 3.5 oz, 5s, in (60°C, 100 g, 5 s, mm)	D5	0.18 – 0.25	N/A (4.5 – 6.5)	N/A					
Viscosity at 400 °F (204°C), #27 spindle, 20 rpm, lbf-sec/ft (Pa.s)	D4402	0.06 – 0.16	N/A (3.0 – 7.5)	N/A					
Viscosity at 376°F (191°C), #27 spindle, 20 rpm, lbf-sec/ft (Pa.s)	D4402	N/A	0.04 – 0.13 (2.0 – 6.0)	0.04 – 0.13 (2.0 – 6.0)					
Flow at 158°F, in. (70°C, mm)		0.2 (5.1) max	0.2 (5.1) max	0.2 (5.1) max					
Heat Stability Flow, in. (mm)	<sup>A</sup>	0.2 (5.1) max	N/A	N/A					
Ductility at 77°F, 2 in./min, in. (25°C, 5 cm/min, cm)	D113	N/A	6 (15) min	3 (8) min					
Ductility at 39°F, 0.4 in./min, in (4°C, 1 cm/minute, cm)	D113	N/A	2 (5) min	0.8 (2) min					
Flexibility at 19°F (– 7°C)	D3111 <sup>B</sup>	N/A	No breaks, no cracks	No breaks, no cracks					
Flash Point, °F (°C)	D92	550 (288) min	550 (288) min	550 (288) min					

<sup>A</sup> Modification to Test Methods: Section 8.4, Specimen Preparation—Heat 2.2 lbs (1000 g) of adhesive in a covered quart can at 424°F (218°C) and maintain at this temperature for 4 h prior to preparing the sample panel according with Section 7.1 of Test Method D5.

<sup>B</sup> Modifications to Test Method D3111: Section 6, Apparatus—Mandrel diameter of 1 in. (25.4 mm). Section 7, Test Specimen—Test specimen dimensions of 1 in. (25.4 mm) wide, 0.125in. (3.18 mm) thick, and 6in. (152 mm) long. Section 8, Conditioning—Conditioning of sample at 19°F (–7°C) 4 h min. Section 10.5, Procedure—Bend the specimen to a 90° arch at a uniform rate in 10 s.

NOTE A1.1—Penetration values represented in SI values provided in the Table A1. are consistent with those found in D5 "Standard Test Method for

Penetration of Bituminous Materials"

### A1.4 Packaging and Labeling

A1.4.1 The adhesive shall be packaged in self-releasing cardboard containers. The containers shall be divided into compartments that provide finished pieces with dimensions not exceeding 10 by 7.5 by 4 in. (252.4 by 189.3 by 101 mm). The label for the container shall clearly show the manufacturer, quantity, lot or batch number, and an indication that the material is bituminous adhesive for pavement markers.

## APPENDIX

### (Nonmandatory Information)

#### X1. STORAGE, PLACEMENT, AND INSTALLATION OF PLOWABLE RAISED PAVEMENT MARKERS

##### X1.1 Storage

X1.1.1 Markers should be stored indoors and should be protected from any source of moisture both during shipment to the jobsite and at the jobsite. The markers should be maintained at a high enough temperature as to preclude moisture condensation, and, at the time of placement, both the markers and their containers should be dry.

##### X1.2 Placement of Plowable Markers

X1.2.1 Before beginning pavement marker application, the contractor should accurately and adequately lay out, by reference points, the location of all pavement markers to ensure their proper placement. Pavement markers should not be placed on pavement surfaces that show visible evidence of cracking, checking, spalling, or failure of underlying base material. If, during the pre-installation layout operation, it is determined that a marker would be placed at a point with one of the aforementioned pavement surface defects or at a pavement construction joint or within the intersection of a driveway or public street as a result of typical marker spacing, the affected marker should be relocated longitudinally a sufficient distance to a point approved by the engineer. The distance the marker may be relocated should not exceed 10 % of the typical marker spacing. Where it would be necessary to

relocate the marker a distance greater than 10 % of the typical marker spacing, the affected marker should be deleted. The reflective face of the marker should be perpendicular to a line parallel to the roadway centerline.

##### X1.3 Installation of Plowable Markers of the Plow Blade Deflecting Type

X1.3.1 At the time of installation, the pavement marker holder should be free of dirt, dust, oil grease, rust, moisture, or any foreign matter that will impair adhesion to the pavement. It should be the contractor's responsibility to clean each contaminated holder by sand blasting or other acceptable procedure to remove all such foreign matter prior to installation.

X1.3.2 The pavement should be machined to match the bottom contour of the marker holder. The holders should be installed within seven days after the slots are cut into the pavement.

X1.3.3 The adhesive should be an epoxy adhesive complying with the formulations given in Table X1.1.

X1.3.4 The epoxy adhesive should be mixed by combining components A and B in a ratio of 1:1 by volume. The epoxy adhesive requires that the mixing operation and placing of the

**TABLE X1.1 Epoxy Adhesive Formulation**

Components	Parts By Weight
<i>Component A:</i>	
Epoxy resin (EPON 828 or equal)	100.0
Titanium dioxide	8.0
No. 13 talc	37.0
<i>Component B:</i>	
N-Aminoethyl piperazine (Jefferson or equal)	25.0
Nonyl phenol	50.0
Talc (Fiberline C-400, Sierra or equal)	70.0
Molacco Black	0.12
Cabasil <sup>A</sup>	0.5

<sup>A</sup> Cabasil was added to inhibit settling.

pavement markers be done rapidly. Any mixed batch that becomes so viscous that it cannot be readily extruded from under the holder under light pressure should not be used. The adhesive should be maintained at 60 to 80°F (15 to 27°C) before mixing. Any heating of the epoxy should be by the application of indirect heat. The adhesive should not be heated above 120°F (49°C).

X1.3.5 During installation of the holders with epoxy adhesive, the ambient temperature and pavement temperature should be at least 50°F (10°C).

X1.3.6 Before installing the markers, the recesses should be brushed or blown clean of loose material and should be dry. Sufficient epoxy should be placed in the recess to ensure that all voids beneath and around the holder are filled so as to create a watertight seal around the holder. The holder should be hand placed into the recess in such a manner as to ensure that the tips of the holder's snowplow deflecting surface(s) are below the pavement surface.

X1.3.7 There should be no buildup of epoxy on either the pavement surface or the holder lip before the marker. Just 1 mm buildup significantly reduces retroreflectance with some designs. There should be no epoxy on the marker lens.

## X1.4 Installation of Recessed Plowable Markers

X1.4.1 *Recommended Dimensions of Groove for Recessed Markers:*

X1.4.1.1 Groove length should be 42 in. (1.1 m) minimum from leading edge of the reflective marker to the beginning of the groove.

X1.4.1.2 Groove depth should be sufficient to accommodate the reflective marker with the top of the marker flush with or recessed to 0.06 in. (1.5 mm) below the pavement surface.

X1.4.1.3 Groove bottom may parallel the pavement surface or be tapered.

X1.4.2 *Application of Recessed Plowable Markers:*

X1.4.2.1 Before installing markers the recesses should be brushed or blown clean of loose material and should be dry.

X1.4.2.2 The marker should be positioned with its top surface flush to 0.06 in. (1.5 mm) below the pavement surface.

X1.4.2.3 Markers should be cemented to the pavement with Rapid Set Type adhesive conforming to AASHTO M237, Type I, Standard Set Type adhesive conforming to AASHTO M237, Type II, or with bituminous adhesive corresponding to the requirements of [Annex A1](#). The engineer should be the judge as

to when Rapid Set Type adhesive has set sufficiently to bear traffic. If rapid set adhesive is to be used the engineer should determine that deterioration of the adhesive caused by accumulated water will not be a problem.

X1.4.2.4 Regardless of the type of adhesive used, markers should not be placed under the following conditions:

(1) When either the pavement or the air temperature is 32°F (0°C) or less when using rapid set epoxy, 50°F (10°C) or less when using standard set epoxy or 40°F (4.4°C) or less when using bitumen.

(2) If the relative humidity of the air is greater than 80 %.

(3) If the pavement is not surface dry.

(4) On new asphalt concrete surfacing until the surfacing has been opened to public traffic for a period of not less than 14 days.

X1.4.2.5 The adhesive should be placed uniformly on the groove surface or on the bottom of the marker in a quantity sufficient to result in complete coverage of the area of contact of the marker with no voids present and with a slight excess after the marker has been pressed in place. The marker should be placed in position and pressure applied until the top surface of the marker is flush with the pavement surface. Excessive adhesive around the edge of the marker, excess adhesive on the pavement, and adhesive on the exposed surfaces of the markers should be immediately removed. Soft rags moistened with mineral spirits conforming to Federal Specification TT-T-291 or kerosine may be used, if necessary, to remove adhesive from exposed faces of pavement markers. No other solvent should be used. The marker should be protected against impact until the adhesive has hardened to the degree designated by the engineer.

X1.4.2.6 The adhesive requires that the mixing operation and placing of the markers be done rapidly. When hand mixing the Standard Set Type adhesive, not more than 1 qt (1 L), and the markers should be aligned and pressed into place within 5 min after mixing operations are started. Any mixed batch which becomes so viscous that the adhesive cannot be readily extruded from under the marker on application of slight pressure should not be used. Rapid Set Type adhesive should not be mixed by hand.

X1.4.2.7 The Rapid Set Type adhesive should be mixed by a two-component type automatic mixing and extrusion apparatus. When machine mixing the Standard Set Type adhesive or the Rapid Set Type adhesive, the markers should be placed within 60 s after the adhesive has been mixed and extruded and no further movement of the marker should be allowed. In addition, no more than 90 s should be permitted between the time the adhesive is pumped into the mixing head and the time this adhesive is in place on the roadway and not subject to further movement. The mixed adhesive should not remain in the mixing head for more than 45 s. Adhesive remaining in the mixing head longer than this period should be wasted before resuming the operation. Automatic mixing equipment for the epoxy adhesive should use positive displacement pumps and should properly meter the 2 components in the specified ratio,  $\pm 5\%$  by volume of either component. At the beginning of each day and at any other time ordered by the engineer, the ratio should be checked by the contractor in the presence of the

engineer. This check should be made by disconnecting the mixing heads, or using suitable bypass valves, and filling two suitable containers with the unmixed components. The mixing head should properly mix the two components so that there is no trace of black or white streaks in the mixed material.

X1.4.2.8 Voids in a cured, undisturbed sample of the mixed adhesive obtained from the extrusion nozzle should not exceed 4 %.

X1.4.2.9 Bituminous adhesive should be dispensed from a thermostatically controlled melter-applicator at a temperature

of 375 to 425°F (191 to 218°C). The adhesive should be stirred frequently to ensure even heating. The adhesive should be dispensed in a puddle larger than the bottom of the marker, and the marker should be dropped onto the puddle as quickly as possible, preferably within 5 s of adhesive placement. The marker should be pressed lightly onto the adhesive. The adhesive will set up in approximately 2 min and typically requires no protection from traffic.

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