Designation: D4796 – 10

Standard Test Method for Bond Strength of Thermoplastic Traffic Marking Materials[1]

This standard is issued under the fixed designation D4796; 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 provides an instrumental means for the determination of thermoplastic traffic marking material bond strengths using cement bricks and loading fixtures.

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

1.3 *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]

C109/C109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)

D16 Terminology for Paint, Related Coatings, Materials, and Applications

D4541 Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers

D5179 Test Method for Measuring Adhesion of Organic Coatings to Plastic Substrates by Direct Tensile Testing

D7234 Test Method for Pull-Off Adhesion Strength of Coatings on Concrete Using Portable Pull-Off Adhesion Testers

D7307 Practice for Sampling of Thermoplastic Traffic Marking Materials

D7308 Practice for Sample Preparation of Thermoplastic Traffic Marking Materials

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

3. Terminology

3.1 The terms and definitions in Terminology D16 apply to this method.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *cement brick, n*—a brick formed by mixing cement and fine sand together and allowing to harden with 210.9 to 351.5 kg/cm^2 (3000 to 5000 psi) compression strength.

3.2.2 *loading fixture, n*—(also referred to as dollies, studs, or jigs) metal fixture round and flat on one end for bonding to test sample and shaped on the other end for attaching to tensile testing device (Fig. 1).

3.2.3 *thermoplastic, n*—traffic marking (same as 3.2.4).

3.2.4 *thermoplastic traffic marking, n*—a highly filled 100 % total solids highway marking system that when heated to a molten state can be extruded or sprayed onto a road surface and when cooled forms a solid durable delineator or road marking thermoplastic usually melted to 218°C (425°F).

4. Summary of Test Method

4.1 The thermoplastic specimen is prepared for this test by first melting a sample to its application temperature under continuous agitation. The specimen is then applied to the specified cement brick using a hot drawdown bar (Fig. 2), heated to 104 ± 2°C (220 ± 5°F), at 3.175 mm (125 mils) thickness. While the thermoplastic is still soft, three cuts are made with a 40.6 mm (1.6 in.) diameter die, heated to 104 ± 2°C (220 ± 5°F), in order to separate the test area from the rest of the drawdown. The die may be heated while submerged in glycerin to prevent thermoplastic from sticking to the die. The test areas are allowed to cool slightly and then three 40.6 mm (1.6 in.) diameter heated loading fixtures are laid on the test areas. The samples are then allowed to cure overnight before determining the bond strength on a tensile testing device.

5. Significance and Use

5.1 The function of this test method is to provide numerical instrumental results indicating the cohesive and/or adhesive bond strength of thermoplastic traffic marking to a specified cement brick substrate.

[1] This test method is under the jurisdiction of ASTM Committee D01 on Paint and Related Coatings, Materials, and Applications and is the direct responsibility of Subcommittee D01.44 on Traffic Coatings.

Current edition approved Dec. 1, 2010. Published March 2011. Originally approved in 1988. Last previous edition approved in 2004 as D4796 – 88 (2004). DOI: 10.1520/D4796-10.

[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.

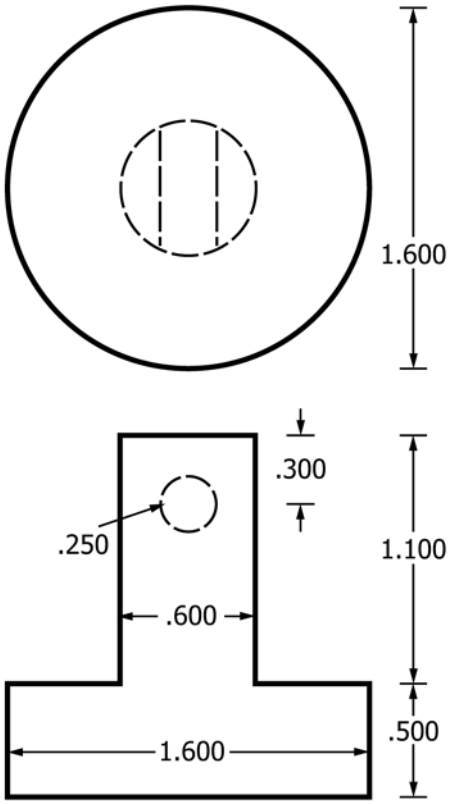

FIG. 1 Loading Fixture

5.2 The use of this test method allows the user and manufacturer to control the quality of the product and make inferences about the performance of the thermoplastic traffic marking product. Results from these tests also provide information helpful in researching and developing thermoplastic traffic marking materials.

5.3 The method has been revised to be more consistent to methodology in other ASTM bond methods for coatings in Test Methods D4541, D5179, and D7234.

5.4 Strict adherence to the procedures outlined is necessary for precision of the test method. Under no conditions should the bond strength be accepted unless there is conformance to the method.

6. Types of Separation in Bond Strength Tests

6.1 *Thermoplastic to Loading Fixture Separation*—This type of separation occurs where there is an insufficient bond between the thermoplastic and loading fixture probably due to insufficient coverage of the thermoplastic to the fixture at the time of placement or too low temperature or both. This separation is acceptable when it exceeds the specified bond strength.

6.2 *Thermoplastic to Thermoplastic Separation*—This type of separation is caused by internal cohesive failure of the thermoplastic. This separation is acceptable when it exceeds the specified bond strength.

6.3 *Thermoplastic to Cement Brick Separation*—This type of separation is caused by the failure of the bond between the thermoplastic specimen and the cement brick. This separation is acceptable when it exceeds the specified bond strength.

6.4 *Cement Brick to Cement Brick*—This type of separation is caused by the internal cohesive failure of the brick. This is due, in most cases, to a bond between the thermoplastic and cement brick that exceeds the cohesive strength of the cement brick. This separation is not acceptable when the bond strength values are lower than specified.

7. Apparatus

7.1 *Loading Fixture (three),* 40.6 mm (1.6 in.) diameter 50.8 sq mm (2 sq in.) area on one end and post for attaching to the tensile testing device and load cell (Fig. 1).

7.2 *Cement Bricks,* 9 by 5.5 by 19 cm (3.75 by 2.5 by 7.75 in.) in size with a compressive strength of 210.9 to 351.5 kg/m^2 (3000 to 5000 psi).

NOTE 1—Cement bricks can be obtained at a local block plant or Block USA. Home improvement paving bricks usually do not have enough cohesive strength. Concrete bricks conforming to Test Method C109/C109M have been used but proved more variable due to migration of a thin veneer of cement to the top of the brick making determinations erratic. The cement bricks may be obtained from local block plants. The term cement brick is common for the industry and is used in this test method extensively.

7.3 *Tensile Testing Equipment* with a minimum capacity of 910 ± 1 kg (200 ± 2 lbs) having a pull-rate capability of 7 mm/min (0.275 in./min).

NOTE 2—The unit should be fitted with a steel frame to hold the cement brick for testing (see Fig. 3).

7.4 *Draw Down Bar,* 5 by 2.5 by 10 cm (2 by 1 by 4 in.) in size capable of laying down a 3.175 mm (125 mil or 0.125 in.) molten thermoplastic film 50.8 mm (2 in.) wide (Fig. 2).

7.5 *Hot Plate,* capable of maintaining 104 ± 2°C (220 ± 5°F).

7.6 *Oven,* capable of maintaining 218 ± 2°C (425 ± 5°F).

7.7 *Die Cutter,* 40.6 mm (1.6 in.) diameter (Fig. 4).

7.8 *Metal Frame* for holding concrete brick (Fig. 3).

8. Sampling

8.1 Samples may be obtained by following Practice D7307.

9. Procedure

9.1 After sampling a batch of road marking thermoplastic by Practice D7307, prepare a representative molten sample for testing by following Practice D7308.

NOTE 3—Premelted block thermoplastic can be sample simply by breaking off the required test size and melting down in the sample manner as prescribed in Practice D7308.

9.2 Heat the draw down bar (see 7.4) to 121°C (250°F) in an oven or on a hotplate.

9.3 Obtain a dry room temperature cement brick that has been brushed or sanded/shot blasted on the side to be coated with thermoplastic. This should remove any loose textured surface material that may negatively affect the results.

9.4 Preheat the 40.6 mm (1.6 in.) diameter die and 3 loading fixtures to 121°C (250°F) in an oven or on a hotplate.

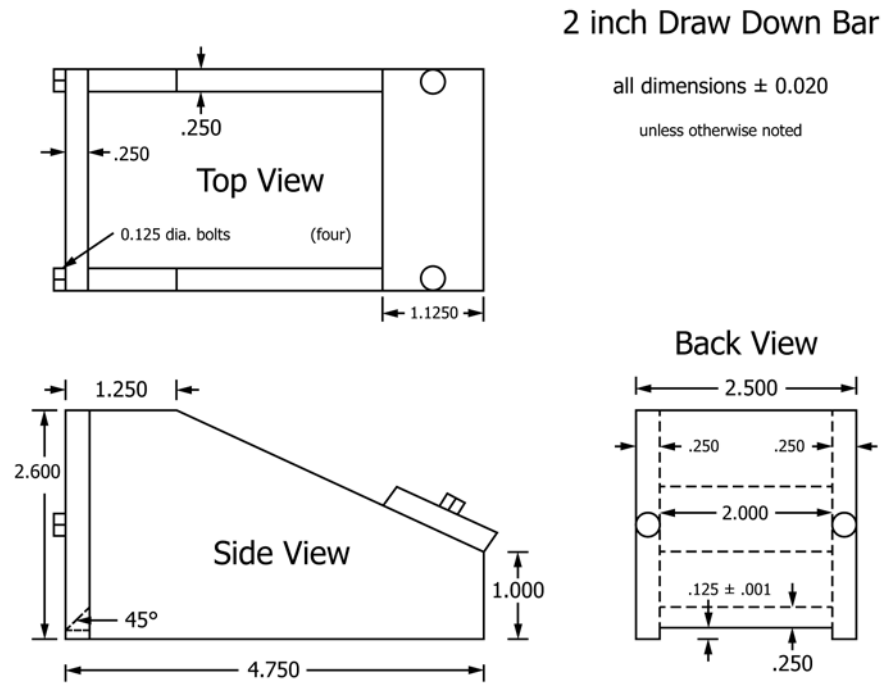

FIG. 2 Drawdown Bar (in inches)

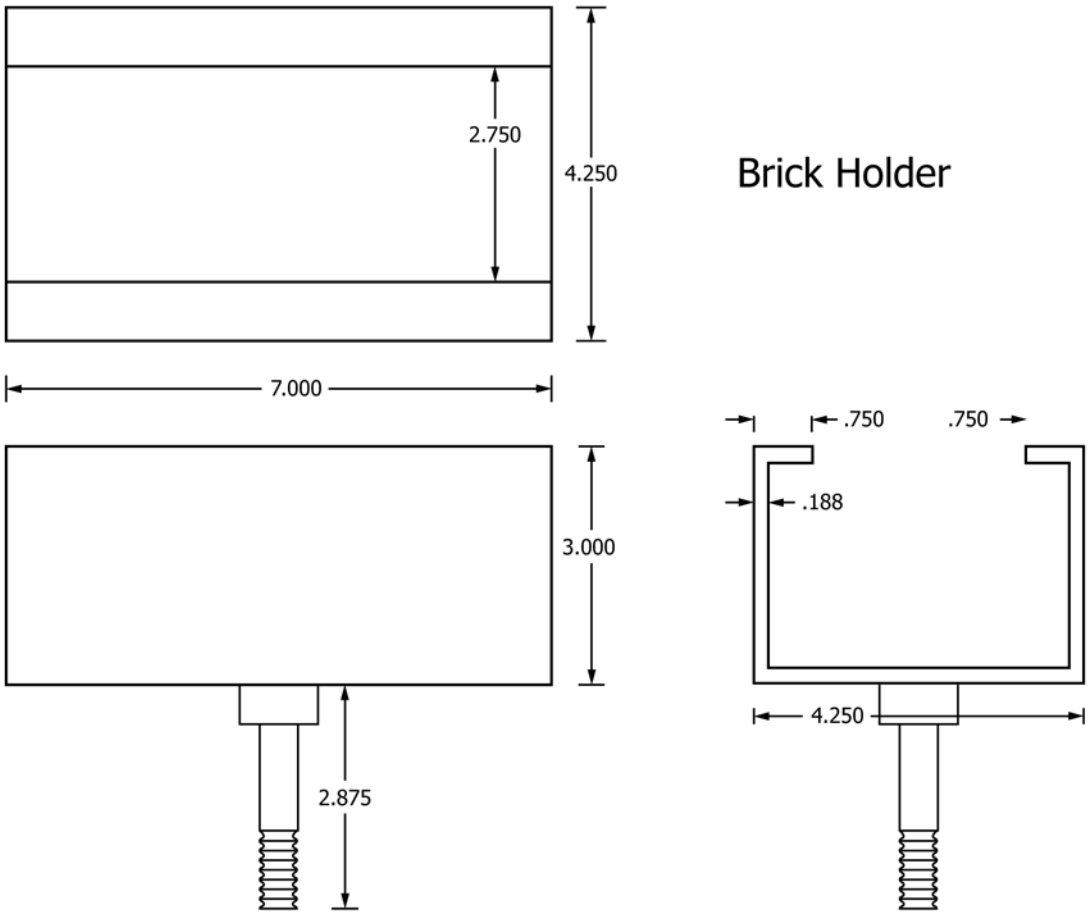

FIG. 3 Brick Holder

9.5 When the thermoplastic specimen is melted to 218°C (425°F) using a 2 oz. ladle, or per manufacturer recommendation under continuous agitation as required in 9.1, obtain a sample of molten material from the container.

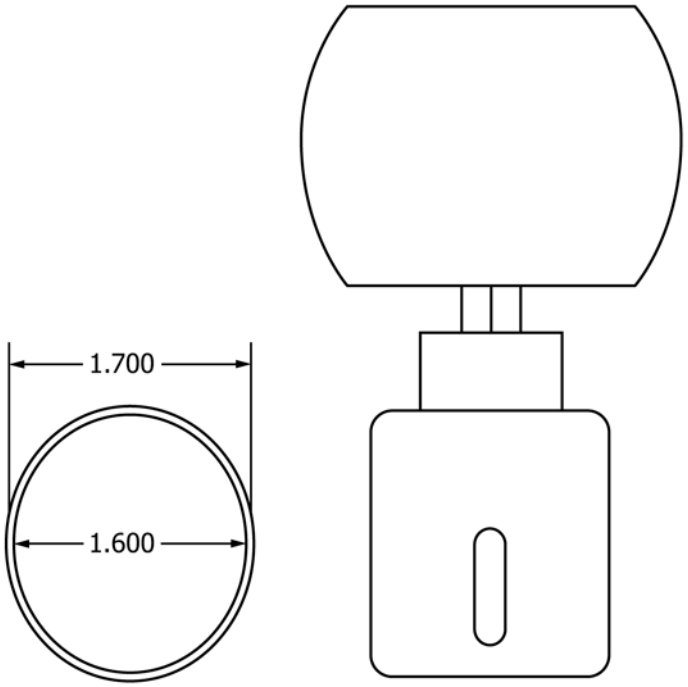

FIG. 4 Die Cutter

9.6 Remove the draw down bar from the hot plate, and immediately place it on the cement brick. Make the draw down the full length of the brick with the melted thermoplastic.

9.7 Remove the 40.6 mm (1.6 in.) diameter die cutter from the oven or hotplate where it has been maintained at approximately 104 ± 2°C (220 ± 5°F).

9.8 Cut out three test areas uniformly spaced along the drawdown thermoplastic.

9.9 Allow the test area to come to room temperature, then place a hot-loading fixture on one of the three test areas allowing the thermoplastic on the surface of the test area to slightly melt and form a tight adhesive bond between the thermoplastic sample and the surface of the loading fixture. This can be aided by applying a slight downward pressure and twisting about ¼ turn on the loading fixture.

9.10 Allow the test sample and loading fixtures to come to room temperature.

9.11 Place the brick in the brick holder attached to the bottom of the tensile testing equipment (Fig. 5).

9.12 Line up the sample to be tested with the universal joint from the load cell.

9.13 Pin the universal joint and the metal jig together. Check that they are in line vertically as much as possible.

9.14 Set the tensile testing device to zero, and pull the loading fixture metal jig at 6.35 mm/min (¼ in./min.).

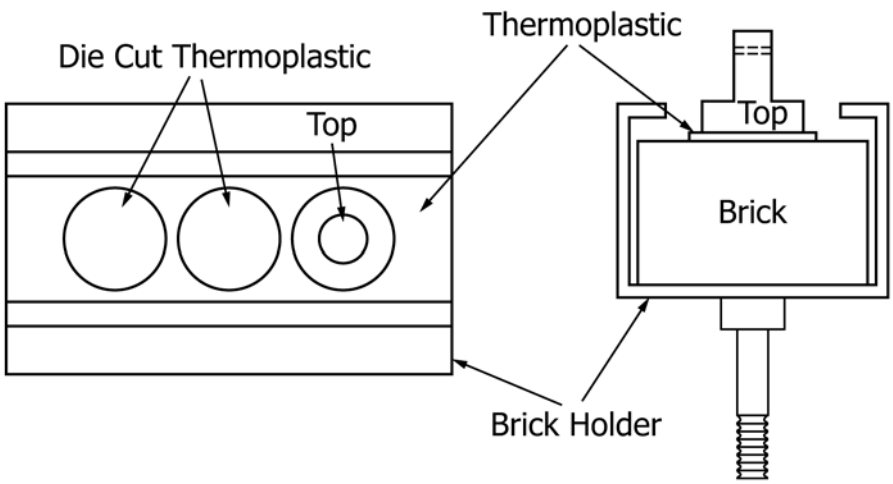

FIG. 5 Brick, Loading Fixtures and Brick Holder

9.15 From the chart recorder or the unit's display, determine the amount of force in kilograms at which the thermoplastic and/or brick fails, and record the results.

9.16 Repeat steps 9.12 – 9.15 to obtain the results of the other two samples.

9.17 Three tests are run on each brick. Separations involving at least 90 % of the thermoplastic area to the cement brick, thermoplastic to thermoplastic and cement brick to cement brick are acceptable for reporting bond strengths. Notations of the type of break should be made for each result. If two of the three tests fails to meet these requirements, then testing should be repeated until these conditions are met.

10. Calculations

10.1 Calculate the bond strength as follows:

10.1.1 Determine the mean of the three readings obtained in 9.15 if the conditions in 9.17 are met.

10.1.2 Divide the mean reading obtained by test area. The result is the bond strength in kilograms per square meter (pounds per square inch).

10.1.3 Discard results which do not meet the requirements of 9.17, and repeat testing until three results with an acceptable failure mode are obtained.

11. Report

11.1 Report the following information:

11.1.1 The type of separation, bond strength, the batch number, color and type of thermoplastic.

11.1.2 The determination of the area of separation is subjective. The area not involved in the separation is usually attached to the loading fixture or cement brick.

12. Precision and Bias[3]

12.1 The precision of this test method is based on an interlaboratory study of Test Method D4796 for Bond Strength of Thermoplastic Traffic Marking Materials, conducted in 2010. A single laboratory, with three technicians, participated in this study. Each of the technicians tested two different materials a total of six times over a period of two days. Every test result reported represents an individual determination. Every test result reported represents an individual determination. Except for the use of only a single laboratory, Practice E691 was followed for the design and analysis of the data; the details are given in ASTM Research Report No. RR:D01-1155.

12.1.1 *Repeatability Limit (r)*—Two test results obtained within one laboratory shall be judges 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.

12.1.1.1 Repeatability limits are listed in Table 1.

TABLE 1 Bond Strength (*psi*)

Material	Average[A] $\bar{x}$	Repeatability Standard Deviation S_r	Repeatability Limit r
White Alkyd Extrude Road Marking Thermoplastic	520.33	89.94	251.84
Yellow Alkyd Extrude Road Marking Thermoplastic	547.67	130.12	364.33

[A] The average of the laboratories' calculated averages.

12.1.2 *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.

12.1.2.1 Reproducibility limits cannot be determined from a single-laboratory study.

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

12.1.4 Any judgment in accordance with statements 12.1.1 and 12.1.2 would normally have an approximate 95 % probability of being correct, however the precision statistics obtained in this ILS must not be treated as exact mathematical quantities which are applicable to all circumstances and uses. The limited number of materials tested and the use of data from just a single reporting laboratory results guarantees that there will be times when differences greater than predicted by the ILS results will arise, sometimes with considerably greater or smaller frequency than the 95 % probability limit would imply. The repeatability limit and the reproducibility limit should be considered as general guides, and the associated probability of 95 % as only a rough indicator of what can be expected.

12.2 *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.

12.3 The precision statement was determined through statistical examination of 36 results, from one laboratory, on two materials. To judge the equivalency of two test results, it is recommended to choose the marking material closest in characteristics to the test material.

13. Keywords

13.1 bond strength; cement brick; thermoplastic—traffic marking

[3] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D01-1155. Contact ASTM Customer Service at service@astm.org.