Designation: D3931 – 08 (Reapproved 2015)

Standard Test Method for Determining Strength of Gap-Filling Adhesive Bonds in Shear by Compression Loading[1]

This standard is issued under the fixed designation D3931; 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 the determination of comparative shear properties of gap-filling adhesives in wood-to-wood joints at specified thicknesses of bondline in the dry condition, when tested on standard specimens under specified conditions of preparation, conditioning, and loading in compression. This test method is intended as an evaluation of gap-filling adhesives such as those used to bond plywood to lumber, lumber to lumber, and other similar materials in building constructions.

1.2 This test method also may be used to determine shear properties of gap-filling adhesives in species of wood and in thicknesses of bondline other than those specified for the comparative tests of shear properties within this test method. All procedures specified herein are applicable, excepting requirements for wood species and specific gravity, and thicknesses of bondlines.

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

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:*[2]

D143 Test Methods for Small Clear Specimens of Timber

D905 Test Method for Strength Properties of Adhesive Bonds in Shear by Compression Loading

D1151 Practice for Effect of Moisture and Temperature on Adhesive Bonds

E171 Practice for Conditioning and Testing Flexible Barrier Packaging

3. Terminology

3.1 *Definitions:*

3.1.1 *gap-filling adhesive, n*—an adhesive capable of forming and maintaining a bond between surfaces that are not close-fitting.

3.1.1.1 *Discussion*—Close-fitting is relative to a given material and industry; for example, standards in construction differ from standards in electronics. Some adhesives will bond by bridging without completely filling the gap; others by filling the gap completely.

4. Significance and Use

4.1 Structural design based on strength-of-materials principles requires knowledge of the mechanical properties of the structural components, including adhesives. By nature of their use, the most important property of adhesive is shear strength.

4.2 Shear strength measured by this test method is suitable for use in adhesive development, manufacturing quality control, and in materials performance specifications, as well as structural design.

5. Apparatus

5.1 *Testing Machine,* having a capacity of about 15 000 lb (6818 kg) in compression or of sufficient capacity to test the adhesive in use. The machine shall be fitted with a shearing tool containing a self-aligning seat to ensure uniform lateral distribution of the load. The machine shall be capable of maintaining a uniform rate of loading such that the load may be applied with a continuous motion of the movable head to maximum load at a rate of 9.20 in. (5.0 mm)/min with a permissible variation of ±25 %. The shearing tool shown in Fig. 1 of Test Method D905 has been found satisfactory. Locate the testing machine in an atmosphere such that the moisture content of the specimens, developed under the conditions prescribed in 7.3, is not noticeably altered during testing.

[1] This test method is under the jurisdiction of ASTM Committee D14 on Adhesives and is the direct responsibility of Subcommittee D14.70 on Construction Adhesives.

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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.

6. Test Specimen and Sample

6.1 Test specimens for adhesive bonds shall conform to the form and dimensions shown in Fig. 1. Prepare bonded assemblies as described in 7.1. Prepare test specimens for testing as described in 7.2.

6.2 Determine mean shear strengths of bonds at bondline thicknesses of 0.006 and 0.060 in. (0.15 and 1.52 mm). Tests for strengths of bonds at other thicknesses, in addition to those specified, shall be optional upon agreement between the manufacturer and the user.

6.3 Test a minimum of 28 specimens, representing seven different bonded assemblies, to determine mean shear strengths of bonds at each bondline thickness.

7. Procedure

7.1 *Preparation of Bonded Assemblies:*

7.1.1 Prepare bonded assemblies with hard maple blocks (*Acer saccharum* or *Acer nigrum*) conditioned as described in 7.3. The blocks shall have a minimum specific gravity of 0.65, based on ovendry weight and ovendry volume (Note 1).

NOTE 1—A method for selecting maple blocks of satisfactory specific gravity is described in the Appendix of Test Method D905. For reference tests, the specific gravity of blocks may be determined in accordance with the Weight and Moisture Content Section under Nail Withdrawal of Test Methods D143.

7.1.1.1 These blocks shall be straight-grained and free of defects, including knots, splits, birdseye, short grain, decay, and any unusual discoloration within the shearing area. The blocks shall be of suitable size so that four test specimens can be cut from one test joint, as shown in Fig. 2. Blocks approximately ¾ by 2½ by 14 in. (19 by 63 by 356 mm) have been found to be satisfactory for this purpose. The moisture content shall be from 8 to 10 % (conditions prescribed in 7.3.1) based on ovendry weight as determined on representative samples in accordance with the final measurement section under radial and tangential shrinkage and the weighing section under moisture determination in Test Methods D143. Surface the blocks just prior to gluing, preferably with a hand-feed jointer. Make sure the surfaces remain unsanded and free from dirt.

7.1.2 Use spacer strips to control bondlines to specified thicknesses between blocks. Spacers shall be wood veneer or plastic, and measure approximately ½ by 3½ in. (13 by 89 mm) long. Place spacers crosswise at the ends and center of the lower test joint block. Apply adhesive in sufficient quantity to ensure squeezeout at the ends of the joint when blocks are under pressure (Note 2).

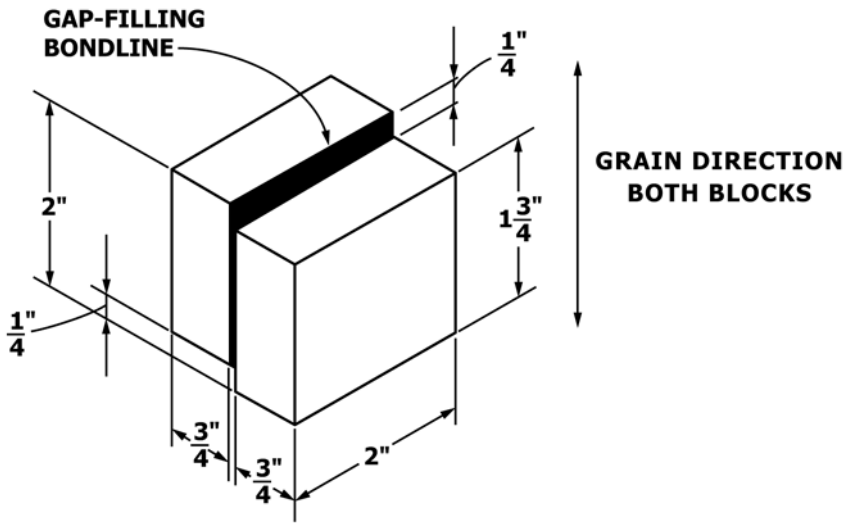
NOTE 2—If the adhesive is to be applied as an extruded bead, the bead should be ⅜ to ½ in. (10 to 13 mm) in diameter to ensure squeezeout in bondline thicknesses near 0.060 in. (1.5 mm). Use a smaller diameter bead of adhesive for thinner bondlines.

7.1.2.1 Take care to avoid air entrapment in the bondline. Do not spread the adhesive closer than ½ in. (13 mm) to any spacer because adhesive may be entrapped between block and spacer, thereby increasing bondline thickness. Assemble the blocks immediately, unless specified otherwise by agreement between the manufacturer and user of the adhesive. Apply a 15-lb (7.0-kg) load uniformly over the entire bond area to ensure firm contact between spacers and blocks of the assembly. Maintain the pressure on test joints at the conditions prescribed in 7.1.

7.1.3 Curing time for bonded assemblies shall be as specified by the manufacturer of the adhesive, or else 30 days in the standard atmosphere (7.3.1).

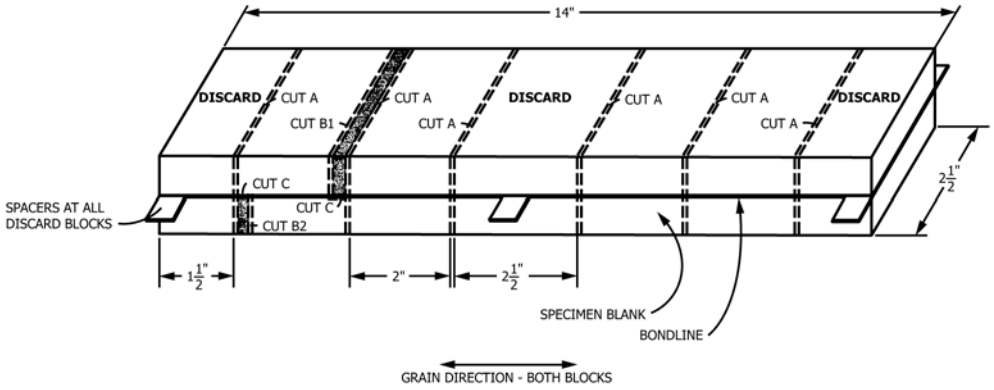
7.2 *Preparation of Test Specimens:*

7.2.1 Joint one edge of each bonded assembly to use as a reference surface in further cutting. Rip-saw the other edge to reduce the width of the assembly to 2 in. (51 mm). Cut 2-in.



Metric Equivalents					
in.	0.064	¼	¾	1¾	2
mm	1.63	6.35	19.05	44.45	50.80

FIG. 1 Form and Dimensions of Test Specimen



Metric Equivalents

in.	1½	2	2½	14
mm	38.1	50.8	63.5	356.0

FIG. 2 Bonded Assembly Showing Method of Cutting Four Test Specimen Blanks

long specimen blanks with the reference surface of the bonded assembly against the crosscut guide of the saw (Cut A, Fig. 2). Then using a stop clamped to the crosscut guide, notch each end of the specimen blank to achieve the 1¾-in. (44.5-mm) bond length (Cuts B1 and B2, Fig. 2). Always make the cut with the reference surface against the crosscut guide. Make Cut B1 extend through the laminate *to* the glueline. Make Cut B2 extend through the laminate and *through* the glueline. The purpose of the latter procedure is to ensure that the adhesive-adhered bond under test is aligned with the shear plane. Make the final cuts (Cut C, Fig. 2) with the block vertical in order to remove waste and complete the steps on either end of the specimen. Keep the reference surface against the crosscut guide. Take special care in making all of the above cuts to ensure that the loading surfaces are smooth, parallel to each other, and perpendicular to the edges and the bondline.

7.2.2 Measure and record the bond width and length to the nearest 0.010 in. (0.25 mm).

7.3 *Conditioning:*

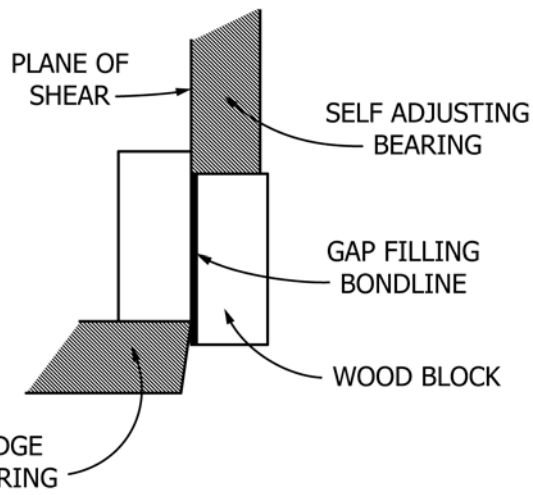


FIG. 3 Side View of Test Specimen Showing Method of Notching Specimen to Ensure Proper Alignment of Shearing Tool and Plane of Shear

7.3.1 Use the standard atmosphere for adhesives for conditioning wood blocks prior to bonding, curing of test joints, and storing of test joints and specimens prior to testing, unless otherwise specified. The standard atmosphere (Specification E171) is a relative humidity of 50 ± 5 % and a temperature of 73.4 ± 3.6°F (23 ± 2°C). Store wood blocks, test joints, and specimens at these conditions for a period of 7 days, or until they reach equilibrium moisture content as indicated by no progressive changes in weight.

7.3.2 Other conditions such as described in Practice D1151 in materials performance specifications, or by mutual agreement between the parties of the test, may be used in addition to the standard atmosphere.

7.4 *Testing*—Place the test specimen in the shearing tool so that the load may be applied as described in 5.1. The position of the specimen with respect to the loading ledge and self-adjusting bearing is shown in Fig. 3. Take special care to ensure that the maple block rests on the lower ledge bearing and abuts the gap-filling bondline. The upper self-adjusting bearing should rest on the opposite maple block and gap-filling bondline. Apply the loading with a continuous motion of the movable crosshead at a rate of 0.20 in./min (5.0 mm/min) to failure as described in 5.1.

8. Calculation

8.1 Calculate the nominal shear stress at failure in pounds-force per square inch (or pascals), and estimate the percentage of wood failure based on the measured bondline area between the two laminations. Record for each specimen.

TABLE 1 Summary of Shear Strength (lbf)

Material, Adhesive	Average Δ ($\bar{x}$)	Repeatability Standard Deviation (Sr)	Reproducibility Standard Deviation (SR)	Repeatability Limit (r)	Reproducibility Limit (R)
Maple to Maple, Adhesive D	1122	103	132	288	368
Maple to Maple, Adhesive E	2850	380	496	1065	1390
Maple to Maple, Adhesive F	11010	1102	1312	3086	3674

8.2 Calculate the mean of the specimens of each group tested as:

$$\bar{x}_i = \sum x_i / n \quad (1)$$

where:

$\bar{x}_i$ = mean shear strength,
x_i = individual shear strengths of specimens in a group, and
n = number of specimens in the group.

8.3 Calculate the standard deviation of the group as:

$$s = \sqrt{\sum \bar{x}_i^{\,2} - \left[\left(\sum x_i\right)^2 / n\right] / (n-1)} \quad (2)$$

8.4 Calculate the standard error of the mean as:

$$s_{\bar{x}} = \sqrt{s^2 / n} \quad (3)$$

8.5 Calculate the mean percentage of wood failure, as shown in 8.2.

TABLE 2 Summary of Wood Failure (%)

Material, Adhesive	Average Δ ($\bar{x}$)	Population Standard Deviation
Maple to Maple, Adhesive D	0	0
Maple to Maple, Adhesive E	0	0
Maple to Maple, Adhesive F	28	25

9. Report

9.1 Report the following information:

9.1.1 Complete identification of the adhesive tested, including type, source, manufacturer's code numbers, form, etc.

9.1.2 Type of adherends in test specimens; that is, species, specific gravity, and grain orientation (that is, edge or flat grain).

9.1.3 Bondline thicknesses tested, as determined from thicknesses of spacers used rather than measured thickness of cured bondline.

9.1.4 Moisture content of wood at time of bonding, method of adhesive application, and time of cure.

9.1.5 Temperature and relative humidity used for preconditioning wood blocks, curing of adhesive, and testing of specimens.

9.1.6 Number of specimens tested at each bondline thickness.

9.1.7 Number of test joints represented at each bondline thickness.

9.1.8 The mean, maximum, and minimum shear stresses at failure, and mean percentage of wood failure for each bondline thickness. Also report the standard deviation of test values for shear stress at failure. Individual test values may be included in the report at the option of either manufacturer or user.

10. Precision and Bias[3]

10.1 *Precision:*

10.1.1 The precision of this test method is based on an interlaboratory study of Test Method D3931 - 93a (2005), using a 0.006-in. gap, conducted in 2006. Each of seven laboratories tested five replicates of specimens prepared using three different adhesives, recording shear strength (lbf). Table 1 summarizes the precision statistics for the statistical analysis on the data collected.

10.1.2 The precision statement was determined through statistical examination of results from seven laboratories, on three materials. These three adhesives were the following:

(1) one-component polyurethane
(2) latex based low-VOC
(3) poly-vinyl acetate

10.1.3 The shear strength precision statistics are expressed in terms of within a laboratory (repeatability) and between-laboratories (reproducibility). Standard deviation (*sr* and *SR*) and 95 % repeatability and reproducibility limits (*r* and *R*) were selected as the precision statistics. See Table 1. Corresponding wood failure mean and standard deviation values are displayed. See Table 2.

10.1.4 Qualification testing for Test Method D3931 compliance specifies testing a sample set of 28 replicates. The shear strength variability of a sample group larger than 5 replicates would represent the adhesive performance estimate with a higher degree of probability.

10.1.4.1 Committee D14 will plan for a future interlaboratory study of Test Method D3931 with the standard's recommended test set of 28 replicates.

10.1.4.2 All of the test specimens were assembled and precut to shear blocks by an accredited laboratory professional technician. The adhesives samples used for test specimen preparation adhesive were from the same batch. The shear blocks were prepared on the same day with the same equipment. Variability contributors such as substrate moisture content, adhesive application rate, assembly time, press pressure, and curing conditions met the standard's tolerance.

[3] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D14-1013. Contact ASTM Customer Service at service@astm.org.

10.1.5 The precision of the test method may be affected by the inherent natural differences of wood mechanical properties.

NOTE 3—The Wood Handbook[4] indicates a 14 % coefficient of variation for clear wood including shear strength parallel to grain and maximum shearing strength.

10.1.5.1 Other sources of variability include test equipment suitability, equipment set-up and accuracy of force measurement. For this study the variability contributed by different laboratories composed of different personnel and equipment was included in the analysis.

10.1.6 *Repeatability*—Two individual test results obtained within one laboratory shall be judged not equivalent if they differ by more than the "*r*" value for that material; "*r*" is the interval representing the critical difference between two test results for the same material, obtained by the same operator using the same equipment on the same day in the same laboratory.

10.1.7 *Reproducibility*—Two individual test results should be judged not equivalent if they differ by more than the "*R*" value for that material; "*R*" is the interval representing the difference between two test results for the same material, obtained by different operators using different equipment in different laboratories.

10.1.8 Any judgement in accordance with statements 10.1.1 or 10.1.2 would have an approximate 95 % probability of being correct.

10.2 *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 can be made.

11. Keywords

11.1 adhesive; gap-filling; shear strength

[4] Available from U.S. Department of Agriculture, Forrest Products Laboratory, One Gifford Pinchot Drive, Madison, WI 53726-2398, http://www.fpl.fs.fed.us.