Designation: D4027 – 98 (Reapproved 2019)

Standard Test Method for Measuring Shear Properties of Structural Adhesives by the Modified-Rail Test[1]

This standard is issued under the fixed designation D4027; 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 describes equipment and procedures to measure the shear modulus and shear strength of adhesive layers between rigid adherends. The equipment may also be used for determining the adhesive's shear creep compliance, the effects of strain history such as cyclic loading upon shear properties, and a failure criteria for biaxial stress conditions such as shear plus tension and shear plus compression.[2]

1.2 High-density wood shall be the preferred substrate. The practical upper limit on the shear modulus that can be measured is determined by the shear modulus of the adherends and by the strain measuring device. Thus, the practical limit of adhesive shear modulus that can be measured using high-density wood adherends is about 690 MPa (1×10^5 psi).

NOTE 1—Wood-base composites, metal, plastic, reinforced plastics, and other common construction materials may also be used for adherends.

1.3 The range of specimen dimensions that can be tested are: width 1.59 to 12.70 mm (0.0625 to 0.500 in.), length 102 to 203 mm (4 to 8 in.), and adherend thickness 13 to 25 mm (0.50 to 1.00 in.). The standard specimen dimensions shall be: width 3.18 mm (0.125 in.), length 203 mm (8 in.), and adherend thickness 19 mm (0.75 in.). Bondline thicknesses from 0.15 to 3.18 mm (0.006 to 0.125 in.) may be tested.

1.4 The values stated in SI units are to be regarded as standard. The values given in parentheses after SI units are provided for information only and are not considered standard.

1.5 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

D905 Test Method for Strength Properties of Adhesive Bonds in Shear by Compression Loading
D907 Terminology of Adhesives
D4442 Test Methods for Direct Moisture Content Measurement of Wood and Wood-Based Materials
E83 Practice for Verification and Classification of Extensometer Systems
E229 Test Method for Shear Strength and Shear Modulus of Structural Adhesives (Withdrawn 2003)[4]

3. Terminology

3.1 *Definitions:*

3.1.1 Many terms in this test method are defined in Terminology D907.

3.1.2 *shear modulus, n*—the ratio of shear stress to corresponding shear strain below the proportional limit. (Compare *secant modulus*.)

3.1.2.1 *Discussion*—The term shear modulus is generally reserved for materials that exhibit linear elastic behavior over most of their stress-strain diagram. Many adhesives exhibit curvilinear or nonelastic behavior, or both, in which case some other term, such as secant modulus, may be substituted.

3.1.3 *shear strain, n*—the tangent of the angular change, due to force between two lines originally perpendicular to each other through a point in the body.

3.1.3.1 *Discussion*—Shear strain equals adherend slip/adhesive layer thickness.

[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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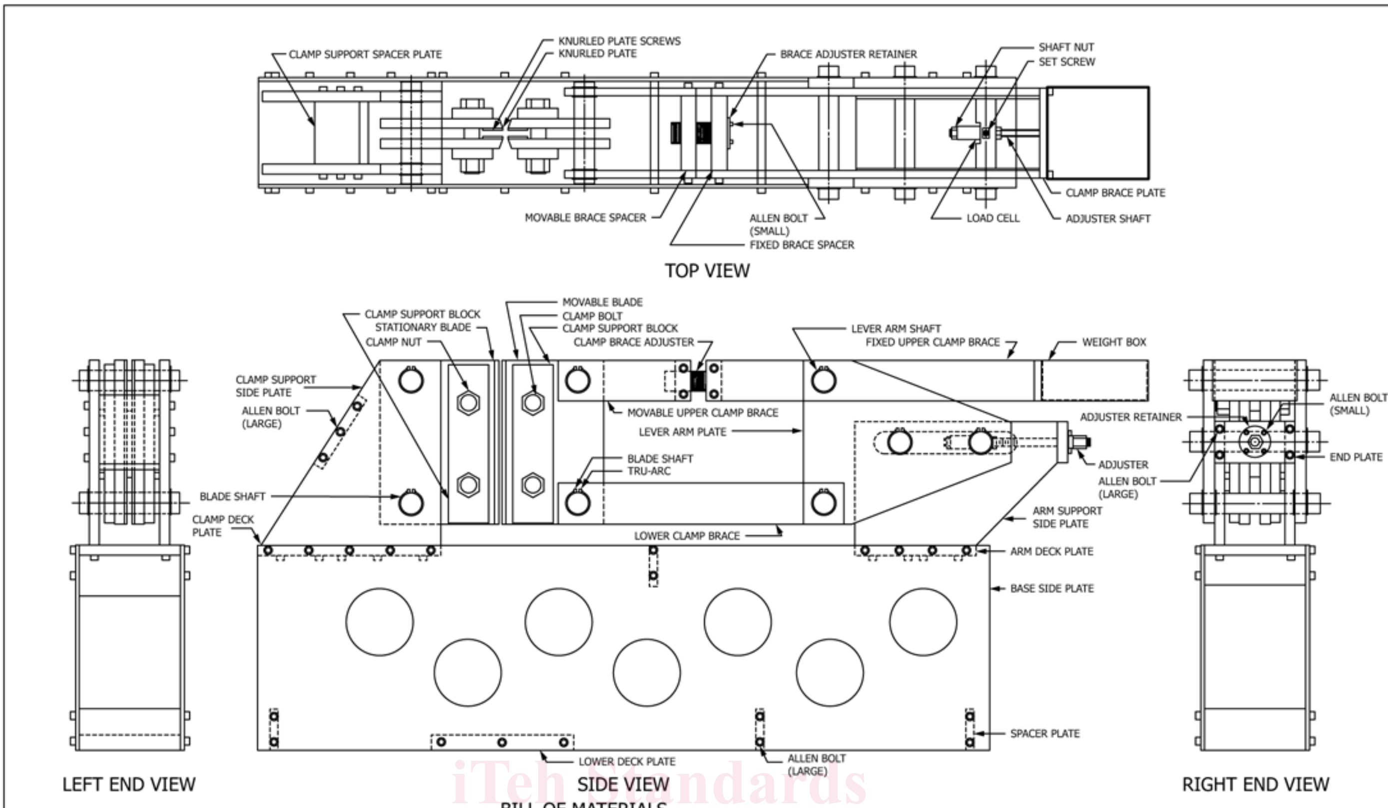
[2] Kreuger, G. P., "Tests for the Shear Properties of Adhesives in Adherend-Adhesive Assemblies," Unpublished report. Michigan Technological Institute, Houghton, MI.

[3] 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.

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



BILL OF MATERIALS

NO.	PART NAME	QTY.	NO.	PART NAME	QTY.	NO.	PART NAME	QTY.	NO.	PART NAME	QTY.	NO.	PART NAME	QTY.	NO.	PART NAME	QTY.
1	ADJUSTER	1	8	BASE SIDE PLATE	2	15	CLAMP SUPPORT BLOCK	4	22	KNURLED PLATE	2	29	MOVABLE BLADE	2	36	TRU-ARC	26
2	ADJUSTER SHAFT	1	9	BLADE SHAFT	4	16	CLAMP SUPPORT SIDE PLATE	2	23	KNURLED PLATE SCREWS	6	30	MOVABLE BRACE SPACER	1	37	WEIGHT BOX	1
3	ADJUSTER RETAINER	1	10	BRACE ADJUSTER RETAINER	1	17	CLAMP SUPPORT SPACER PLATE	1	24	LEVER ARM PLATE	2	31	MOVABLE UPPER CLAMPBRACE	2			
4	ALLEN BOLT (LARGE)	76	11	CLAMP BOLT	4	18	CLAMP NUT	4	25	LEVER ARM SHAFT	4	32	SET SCREW	1			
5	ALLEN BOLT (SMALL)	8	12	CLAMP BRACE ADJUSTER	1	19	END PLATE	1	26	LOAD CELL	1	33	SHAFT NUT	2			
6	ARM DECK PLATE	1	13	CLAMP BRACE PLATE	1	20	FIXED BRACE SPACER	1	27	LOWER CLAMP BRACE	2	34	SPACER PLATE	4			
7	ARM SUPPORT SIDE PLATE	2	14	CLAMP DECK PLATE	1	21	FIXED UPPER CLAMP BRACE	2	28	LOWER DECK PLATE	1	35	STATIONARY BLADE	2			

MODIFIED RAIL SHEAR APPARATUS

SCALE 1/2" = 1'-0" DATE 10/79 DRAWN D.Z. NUMBER 1046 PAGE 1 OF 2

FIG. 1 Top, Side, and End Views of the Modified-Rail Shear Apparatus

3.1.4 *shear strength, n*—in an adhesive joint, the maximum average stress when a force is applied parallel to the joint.

3.1.4.1 *Discussion*—In most adhesive test methods, the shear strength is actually the maximum average stress at failure of the specimen, not necessarily the true maximum stress in the material.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *load, n*—the force applied to the specimen at any given time.

3.2.2 *load-slip diagram, n*—a diagram in which corresponding values of load and slip are plotted against each other. Values of load are usually plotted as ordinates and values of slip as abscissas.

3.2.3 *normal stress, n*—the stress component perpendicular to a plane on which the forces act, that is, perpendicular to the plane of the bondline.

3.2.4 *proportional limit, n*—the maximum stress that a material is capable of sustaining without significant deviation from proportionality of stress to strain.

3.2.5 *secant modulus, n*—the slope of the secant drawn from the origin to any specified point on the stress-strain curve.

3.2.5.1 *Discussion*—Modulus is expressed in force per unit area (megapascals, pounds-force per square inch, etc.).

3.2.6 *shear stress, n*—the stress component tangential to the plane on which the forces act, that is, in the plane of the bondline.

3.2.7 *slip, n*—the relative collinear displacement of the adherends on either side of the adhesive layer in the direction of the applied load.

3.2.7.1 *Discussion*—This term differs from that of the stress-strain diagram in that load and slip are not divided by bond area and bond thickness (the constants that convert load to stress and slip to strain). In actual practice, stress-strain information is generally collected in the form of a load-slip diagram for ease in plotting.

3.2.8 *stress–strain diagram, n*—a diagram in which corresponding values of stress and strain are plotted against each other. Values of stress are usually plotted as ordinates (vertically) and values of strain as abscissas (horizontally).

4. Summary of Test Method

4.1 Shear force is applied to the adhesive through the adherends by a modified-rail shear tool such as shown in Fig. 1. The adherends are firmly clamped between two pairs of rigid rails as shown in Fig. 2. One pair is fixed and the other is movable. The rigid rails limit undesired adherend deformation during testing. The pair of movable rails is fixed to two

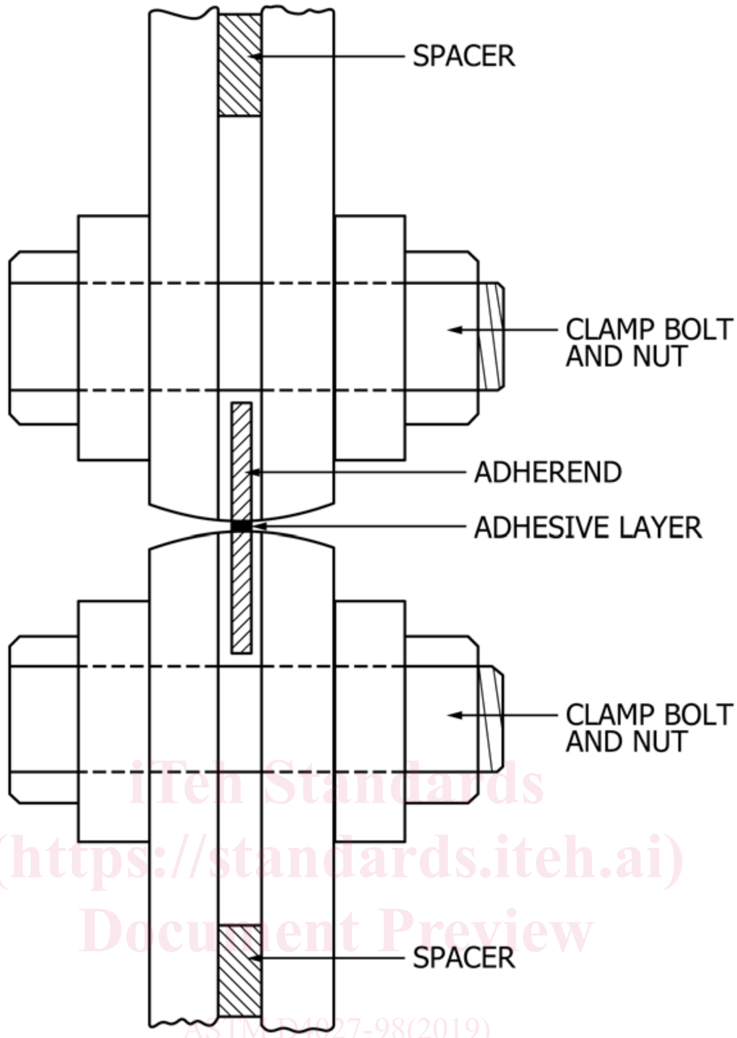


FIG. 2 Top View of the Rail Clamps Showing How the Specimen Is Gripped for Testing

counter-moment pivot arms. These arms restrict the attached rails (and clamped adherend) to collinear motion with respect to the fixed rails (and clamped adherend). The results of using this shear tool are nearly uniform stress and strain distributions and the reduction of normal stress in the adhesive layer under load. Such conditions are necessary for accurate measurement of the adhesive shear properties.

4.2 A known amount of uniform tensile or compression force can be applied to the adhesive layer by the shear tool in order to develop a fracture criteria for the adhesive under combined states of stress, such as shear plus tension, or shear plus compression, which commonly occur in bonded structures. Fig. 3 shows combined shear and tensile forces on the clamped specimen.

4.3 The basic output of the test method is the bond shear strength determined as the shear stress at failure, and the stress-strain diagram determined from the plot of load on the shear tool versus the shear displacement of the bond line.

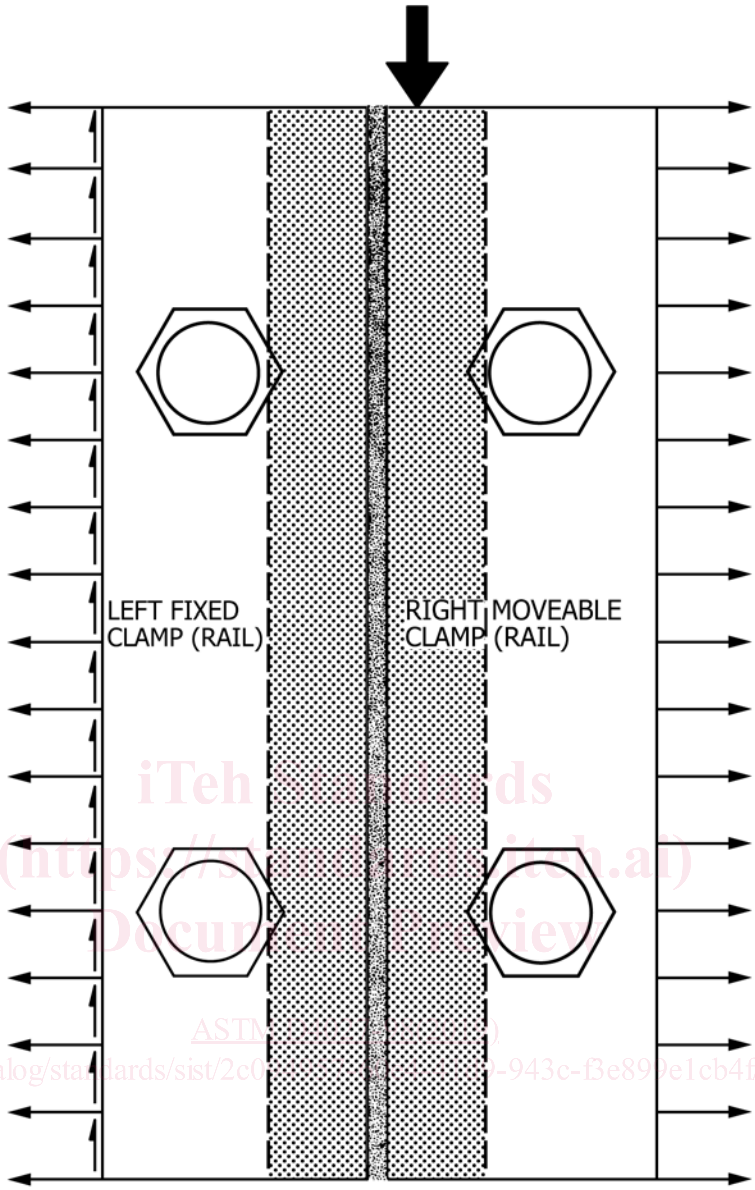
4.4 Bond strength and the stress-strain diagram may be obtained for a variety of environmental and loading conditions. Specific recommendations are made for a minimum test program.

5. Significance and Use

5.1 Structural design based on strength of materials principles or the theory of elasticity requires knowledge of the mechanical properties of the structural components, including adhesives. By the nature of their use, the most important adhesive properties are shear modulus and shear strength. A torsion test, such as described in Test Method E229, is theoretically the most accurate method for measuring adhesive shear properties. It is, however, impractical in many situations. For example, certain materials of construction are not readily adaptable to fabricating the thin-walled cylinders used as adherends in the torsion test. The modified-rail test does not have this disadvantage.

5.2 Two undesirable conditions occur in the modified-rail test specimens that do not occur in butt-joined cylinders; nonuniform shear-stress distribution along the joint, and the addition of some undefined combination of tension and compression stresses to the shear stress at a given location in the joint. The modified-rail shear tool minimizes but does not eliminate these undesirable effects.

5.3 Shear modulus, strength, and other properties are measured by the modified-rail method.



NOTE 1—During a shear only test the horizontal arrows (tension forces) would be absent.

FIG. 3 Side View of the Rail Clamps Showing the Forces On the Clamps (Specimen) During Combined Shear and Tension Loading

6. Apparatus

6.1 *Universal Testing Machine:*

6.1.1 The universal testing machine shall have a minimum load capacity of 8900 N (2000 lbf), and a range of crosshead speed from 0.317 to 10.16 mm/min (0.0125 to 0.40 in./min). A minimum vertical space of 508 mm (20 in.) and horizontal space of 305 mm (12 in.) is required to install the shear tool in the testing machine.

6.1.2 The testing machine shall have a device capable of reading the load to the nearest 4.5 ± 0.9 N (1.0 ± 0.2 lbf). This readout device should preferably be an electronic load cell to facilitate simultaneous recording of load with the adhesive deformation.

6.2 *Modified-Rail Shear Tool:*

6.2.1 A shear tool suitable for this test method is illustrated in Fig. 1, Fig. 2, Fig. 4, Fig. 5, and Fig. 6.

6.2.2 The shear tool is fitted with a threaded bolt (Adjuster, Fig. 1[5]) to apply normal force for combined stress studies. The magnitude of the normal force is constant from the outset of the test. The bolt has a strain gage bonded to it that, with a suitable readout device and calibration, can be used to set the desired normal force.

6.3 *Slip or Strain Gage*—Since the shear strain of adhesive layers will normally be very small, an ASTM Class A or Class

[5] Complete detail drawings of the modified-rail shear apparatus are available from the Forest Products Laboratory, Forest Service, U.S. Department of Agriculture, Madison, WI 53705.