Designation: D3983 – 98 (Reapproved 2011)

# Standard Test Method for Measuring Strength and Shear Modulus of Nonrigid Adhesives by the Thick-Adherend Tensile-Lap Specimen[1]

This standard is issued under the fixed designation D3983; 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 a method of measuring the shear modulus and rupture stress in shear of adhesives in bonded joints. The method employs lap-shear specimens with wood, metal, or composite adherends, with adhesives having shear moduli ranging up to 700 MPa (100 000 psi). This test method is suitable generally for joints in which the ratio of adherend tensile modulus to adhesive shear modulus is greater than 300 to 1. It is not suitable for adhesives that have a high shear modulus in the cured state and that also require elimination of volatile constituents during cure.

1.2 The values stated in SI units are to be regarded as 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]

D143 Test Methods for Small Clear Specimens of Timber

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

D907 Terminology of Adhesives

D1151 Practice for Effect of Moisture and Temperature on Adhesive Bonds

D2651 Guide for Preparation of Metal Surfaces for Adhesive Bonding

E6 Terminology Relating to Methods of Mechanical Testing

E83 Practice for Verification and Classification of Extensometer Systems

E104 Practice for Maintaining Constant Relative Humidity by Means of Aqueous Solutions

E229 Test Method for Shear Strength and Shear Modulus of Structural Adhesives (Withdrawn 2003)[3]

## 3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in this test method, refer to Terminologies E6 and D907.

3.1.2 *initial tangent modulus, n*—the slope of the stress-strain curve at the origin.

3.1.3 *nominal stress, n*—the stress at a point calculated on the net cross section by simple elastic theory without taking into account the effect on the stress produced by discontinuities such as holes, grooves, fillets, etc.

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

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

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

3.1.6.1 *Discussion*—Modulus is expressed in force per unit area (MPa, lb/in.$^2$, etc.).

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

3.1.7.1 *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.

3.1.8 *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.

3.1.8.1 *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.

Current edition approved Jan. 1, 2011. Published January 2011. Originally approved in 1981. Last previous edition approved in 2004 as D3983 – 98 (2004). DOI: 10.1520/D3983-98R11.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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

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

3.1.9.1 *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.

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

3.1.10.1 *Discussion*—Nominal shear stress equals load/bond area.

3.1.11 *strain, n*—the unit change due to force, in the size or shape of a body referred to its original size or shape.

3.1.12 *stress, n*—the intensity at a point in a body of the internal forces or components of force that act on a given plane through the point.

3.1.13 *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).

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 (vertically) and values of slip as abscissas (horizontally).

3.2.2.1 *Discussion*—Stress-strain behavior is commonly recorded in the form of a load-slip diagram. The difference between the two is simply one of scale. Load is divided by bond area to obtain stress and slip is divided by adhesive layer thickness to obtain strain. Examples of various types of load-slip diagrams and modulus are shown in Figs. 1-3.

3.2.3 *rate of strain, n*—rate of slip per unit adhesive thickness.

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

3.3 *Symbols:*

3.3.1 $c$ = half the overlap length = $L/2$, mm or in.

3.3.2 $\hat{G}$ = estimate of shear modulus of adhesive, MPa or psi.

3.3.3 $G$ = shear modulus of adhesive, MPa or psi.

3.3.4 $E$ = tensile modulus of adherend, MPa or psi.

3.3.5 $t$ = thickness of adherend, mm or in.

3.3.6 $\eta$ = thickness of adhesive, mm or in.

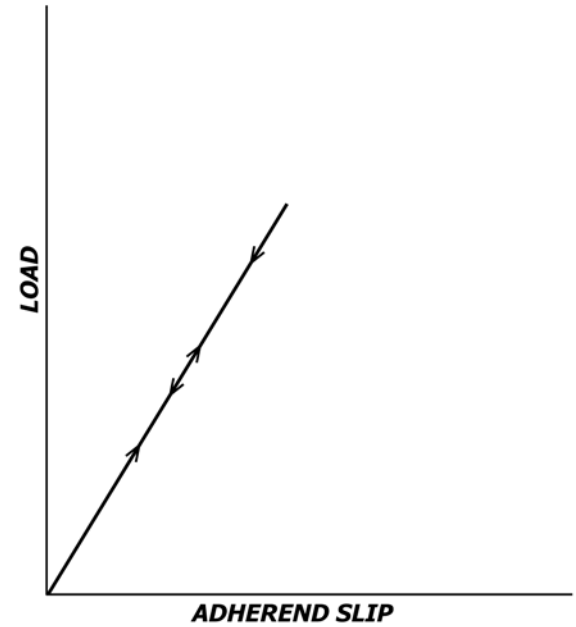
3.3.7 $P_{max}$= failure load for the bond, N or lbf.

3.3.8 $L$ = overlap length, mm or in.

3.3.9 $A$ = bond area, $mm^2$ or $in.^2$.

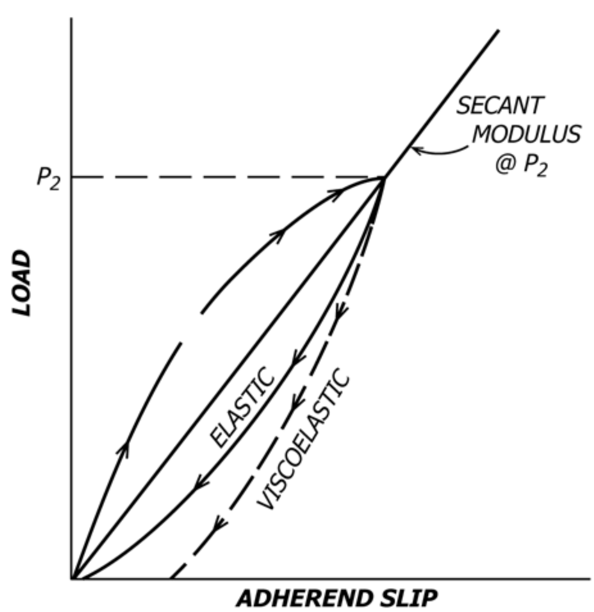
3.3.10 $\delta$ = adherend slip at load equivalent to 0.1 $P_{max}$, mm or in.

3.3.11 $\bar{\tau}_{max}$= maximum nominal shear stress sustained by the bond, MPa or psi.




NOTE 1—Case load and unload diagrams and modulus line are congruent.

**FIG. 1 Load-Slip Diagram of Linear Elastic Adhesive Under Cyclic Low-Level Loading**

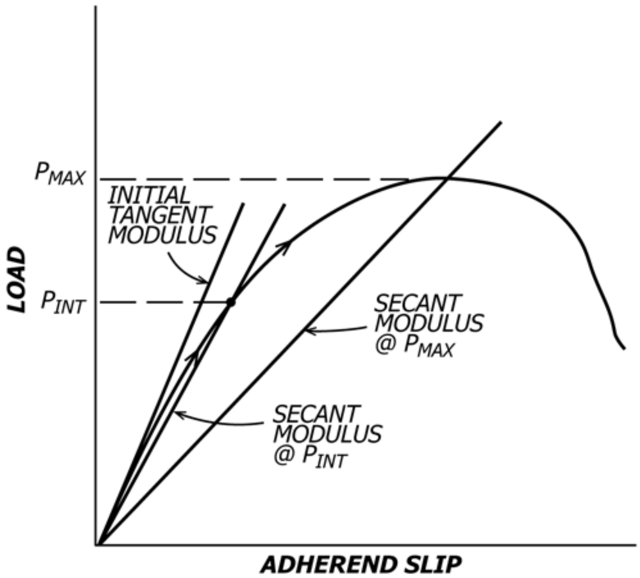



NOTE 1—The modulus is represented by the secant modulus line at some load $P_2$ less than the load to cause failure.

**FIG. 2 Load-Slip Diagram of Nonlinear Adhesive Under Cyclic Low-Level Loading Showing Both Elastic and Viscoelastic Recovering Diagrams**

## 4. Summary of Test Method

4.1 Lap-shear specimens are prepared with the adhesive in question using selected adherends. The load-deformation properties of the specimens are measured under specific recommended conditions to yield a "first estimate" of adhesive shear modulus. This estimate is used to determine the optimized joint geometry for best attainable uniformity of stress distribution in




NOTE 1—The modulus may be represented by the initial tangent, the secant drawn to the ultimate load, or the secant drawn to some intermediate load.

**FIG. 3 Load-Slip Diagram of Adhesive Loaded to Failure**

the joint. A second set of specimens is prepared having the optimized joint geometry. The final values for load-deformation properties are then measured under a variety of controlled environmental and experimental conditions.

4.2 The test method is based upon the theoretical analysis by Goland and Reissner[4] relating stress concentrations (that is, nonuniformity) in single-lap joints to the geometry of the joint and the mechanical properties of the materials involved. The controlling factor in the Goland and Reissner equations is a composite of essentially three ratios which can be manipulated to improve the stress uniformity in the joint, and thereby control the accuracy of measurement. Stress uniformity is improved by (*1*) increasing the adherend tensile modulus in relation to the shear modulus of the adhesive, and by (*2*) increasing adherend and adhesive thickness while minimizing overlap length. Because of these relationships, the practice was developed to use high-modulus adherends in thick cross sections.

## 5. Significance and Use

5.1 This test method is capable of providing shear modulus and shear strength values for adhesives with accuracy suitable for use by design engineers in predicting the characteristics of building assemblies bonded with nonrigid adhesives. Adhesive formulators will also find the method useful during the development of new adhesive systems. In general, the thick adherend lap-shear test is a useful tool in research during studies of both short- and long-term load-deformation properties of adhesives. This thick adherend lap-shear test yields a uniformity of stress distribution approaching that obtained in thin tubular butt joints subjected to torsion, which is considered to be a condition of pure shear.

5.2 The user is cautioned that pure shear strength cannot be obtained by this test method, because some tensile and compression stresses and stress concentrations are present in the joint. The estimate of shear strength by this test method will be conservative. If pure shear strength is demanded, then Test Method E229 should be used.

## 6. Equipment

6.1 *Test Machine*—A tension test machine with electronic load cell capacities of 0 to 100 and 0 to 1000 kg (0 to 200 and 0 to 2000 lb) is satisfactory for this test method. The machine should have a loading rate capability of 0 to 200 kg/min (0 to 400 lb/min) or a crosshead movement rate of 0 to 1 mm/min (0 to 0.040 in./min). Closed-loop control of load level and loading rate, or crosshead position and movement rate, is desirable to facilitate testing under controlled cyclic loading conditions. A working space approximately 450 by 450 mm (18 by 18 in.) is desirable to accommodate the specimen grips and the installation of a chamber for environmental control. In-line tension grips, shown in Fig. 4, are used for transmitting the load to the specimen.

6.2 *Slip Gage and Signal Conditioner:*

6.2.1 The shear strain in adhesive layers is usually small. Thin layers of relatively rigid adhesives (greater than 50 MPa (7000 psi)) require an ASTM Class A extensometer. Class B-1 or B-2 extensometers suffice for thicker layers and more flexible adhesives. Extensometer classes are described in Practice E83.

6.2.2 A mechanical-electrical transducer, the linear variable differential transformer (LVDT), is well suited for these tests. The LVDT with suitable signal conditioning will satisfy the requirements of Class B and A extensometers. They are rugged enough to remain fastened to the specimen through failure if the gage is properly designed.

6.2.2.1 The LVDT should have a linear output over a displacement range of ±2.5 mm (±0.10 in.) to accommodate adhesive layers varying in shear modulus and thickness.

6.2.2.2 The LVDT transducers with signal conditioner should provide several ranges of displacement resolution—between 0.0005 and 0.5 mm/cm ($5 \times 10^5$ and 0.05 in./m) of chart paper.

6.2.3 The slip gage shall employ two LVDTs as described in 6.2.2, positioned in such a manner as to measure and compensate for rotation of the adherends as well as slip.

6.2.4 A gage design that has been found to compensate satisfactorily for adherend rotation is shown in Fig. 5, Fig. A1.1, and Fig. A1.2. The gage consists of three components: the gage itself on which two LVDTs are mounted, the follower, and a gage block. The gage and follower attach to opposing adherends by clamping knife edges. One knife edge on each component may be advanced or retracted by a captive screw. The gage block is placed between the gage and follower to align the knife edges. The gage is clamped to the stationary or downward moving adherend and the follower to the upward moving adherend, so the LVDT core moves out of the LVDT during loading. This prevents damage to the LVDT upon

[4] Goland, M., and Reissner, E., "The Stresses in Cemented Joints," *Journal of Applied Mechanics*, November 1944, pp. A17–A27.