



# Standard Test Method for Transverse Shear Strength of Fiber-reinforced Polymer Matrix Composite Bars<sup>1</sup>

This standard is issued under the fixed designation D7617/D7617M; 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 reappraisal. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reappraisal.

## 1. Scope

1.1 This test method specifies the test requirements for (FRP) composite smooth round rods and textured bars for determining the transverse shear strength via a double shear fixture. FRP rods and bars are often loaded in transverse shear when these elements are used as dowels in concrete pavements, as stirrups in concrete beams, or as shear reinforcements in glued-laminated wood beams, for example.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.2.1 Within the text, the inch-pound units are shown in brackets.

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:<sup>2</sup>

**A615/A615M** Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement

**D883** Terminology Relating to Plastics

**D3878** Terminology for Composite Materials

**D5229/D5229M** Test Method for Moisture Absorption Properties and Equilibrium Conditioning of Polymer Matrix Composite Materials

**D7205/D7205M** Test Method for Tensile Properties of Fiber Reinforced Polymer Matrix Composite Bars

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee D30 on Composite Materials and is the direct responsibility of Subcommittee D30.10 on Composites for Civil Structures.

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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.

**E4** Practices for Force Verification of Testing Machines

**E6** Terminology Relating to Methods of Mechanical Testing

**E122** Practice for Calculating Sample Size to Estimate, With Specified Precision, the Average for a Characteristic of a Lot or Process

**E456** Terminology Relating to Quality and Statistics

## 3. Terminology

3.1 Terminology in **D3878** defines terms relating to high-modulus fibers and their composites. Terminology in **D883** defines terms relating to plastics. Terminology in **E6** defines terms relating to mechanical testing. Terminology in **E456** defines terms relating to statistics and the selection of sample sizes. In the event of a conflict between terms, Terminology in **D3878** shall have precedence over the other terminology standards.

### 3.2 Definitions of Terms Specific to This Standard:

3.2.1 *bar, n*—a linear element, with a substantially round cross section, often with surface undulations or a coating of particles that promote mechanical interlock with concrete.

3.2.2 *double shear fixture, n*—a test fixture that results in the desired shear force being applied to two distinct sections of the specimen.

3.2.3 *failure, n*—cleavage of the bar under test into three pieces or into two pieces where the second non-cleaved shear plane is highly damaged.

3.2.4 *nominal cross sectional area, n*—a measure of cross sectional area of a bar, determined over at least one representative length, used to calculate stress.

3.2.5 *projected outer diameter, n*—the smallest diameter of a circle through which a bar, with its undulations or coatings, will pass. The bar may touch the circle but must pass through without undue force.

3.2.6 *rod, n*—a bar with a smooth circular cross section and no texture or deformations.

3.2.7 *standard cross sectional area, n*—the cross sectional area of a standard numbered steel concrete reinforcing bar as given in **A615/A615M**, Table 1.

3.2.8 *surface undulation, n*—variation in the area, orientation, or shape of cross section of a bar along its length,

intended to enhance mechanical interlock between a bar and concrete, made by any of a number of processes such as, for example, indentation, addition of extra materials, and twisting.

### 3.3 Symbols:

3.3.1  $A$ —nominal or standard cross sectional area of a rod or bar, see [D7205/D7205M](#).

3.3.2  $P_S$ —maximum shear force carried by specimen N [lbf].

3.3.3  $\tau_u$ —transverse shear strength, MPa [psi].

## 4. Summary of Test Method

4.1 A length of fiber-reinforced polymer (FRP) rod or bar is fitted into a double shear fixture with appropriate cutting blades and clamped into place. The shear fixture is mounted into a universal mechanical testing machine and monotonically loaded to failure while recording force and crosshead displacement.

## 5. Significance and Use

5.1 This test method for transverse shear strength is intended for use in laboratory tests in which the principal variable is the size or type of FRP bars. The test may be used for smooth round rods or on bars with a textured or undulating surface added to promote bond of the bars to Portland cement concrete. This test method establishes values of transverse shear strength for material specifications, quality control, quality assurance, research and development, and may also be used for structural design purposes.

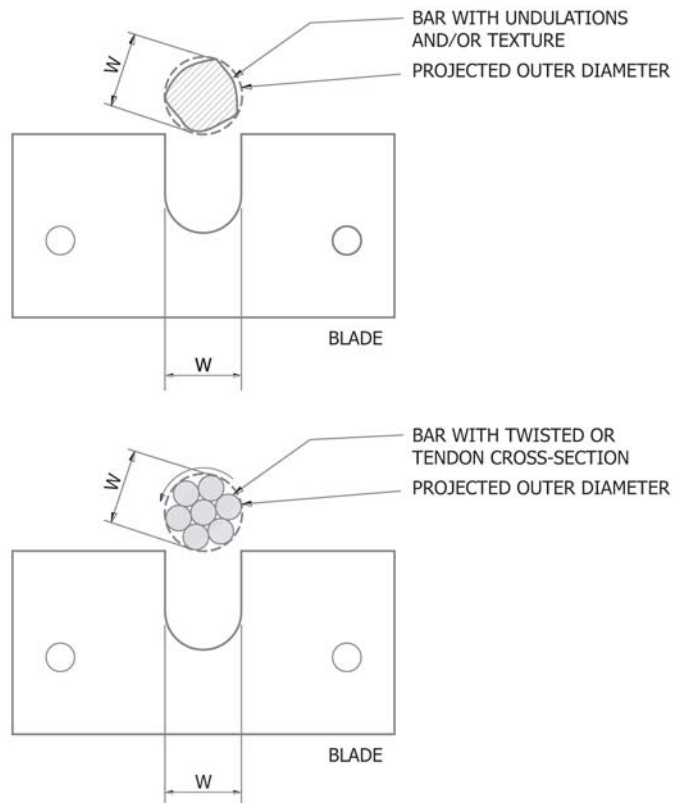
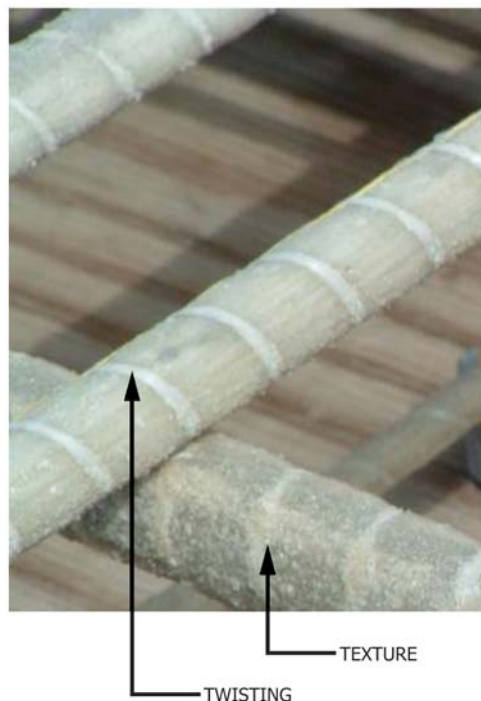
5.2 Experience with this test method and the accompanying fixture is primarily with smooth rods and textured bars with diameters ranging from 6 mm to 25 mm [0.25 in. to 1 in.]. The method may be used for rods or bars of larger diameters, but the overall geometry of the test fixture may need to be increased.

## 6. Interferences

6.1 *Blade Alignment*—The two lower and one upper blade used for shearing the specimen are machined to fit the projected outer diameter of the bar. The slot width and diameter of the blades should be selected so that the bar fits snugly into the fixture, but does not bind. The test results may be sensitive to the slot width for bars which have significant texture or deformations. See [Fig. 1](#).

6.2 *Surface Texture*—The method has been used with textured bars with surface roughness amplitudes of up to  $\pm 5\%$  variation in diameter relative to the average bar diameter as measured with a dial caliper. Use on bars with greater variation in surface roughness or regions with substantially-reduced cross-sections may lead to increased scatter in test results or failure of the specimens away from the two shearing planes.

6.3 *Measurement of Cross Sectional Area*—The nominal cross sectional area of textured or undulating bars is measured by immersing a prescribed length of the specimen in water to determine its buoyant weight, as described in [D7205/D7205M](#). Bar configurations that trap air during immersion (aside from minor porosity) cannot be assessed using this method. This



NOTE 1—The blades should fit snugly around the bar without binding.

**FIG. 1 Potential Interference for Undulating or Textured Bar**

method may not be appropriate for bars that have large variations in cross sectional area along the length of the bar.

**6.4 Clamping Force**—The bar should be firmly clamped to the bar seats before testing. Testing without sufficient clamping will lead to lower apparent transverse shear strength results. Experience with the fixture and small-diameter glass-reinforced FRP rods has shown that two set screws on one end of the bar and one set screw on the other end is sufficient for this clamping.

**6.5 System Alignment**—The test is typically completed on universal testing machine with compression platens. Care should be taken that bottom compression platen is completely flat and large enough for entire surface of test fixture to bear, and is perpendicular to the axis of loading.

## 7. Apparatus

**7.1** The test fixture consists of two bar seats, two lower blades, and two guides machined from steel. These parts are bolted together with two threaded rods with washers and nuts

as shown in Figs. 2 and 3. Thin shim stock (suggested thickness of 0.08 mm [0.003 in.]) may be placed between the bar seats and the guides to ensure a close running fit of the upper blade between the two lower blades (see Fig. 5a and b and Fig. 6a and b). The upper blade is loose, and is fit onto the bar prior to testing.

**NOTE 1**—Other versions of this test fixture have been developed that combine the two lower bar seats into one unified component with a fixed gap of 50 mm [2.0 in.] between the bar seats to allow for insertion of the lower blades. These fixtures are acceptable for use with this standard but the fit between the lower and upper blades is not adjustable.

**7.2 Dimensional Tolerances**—Dimensional tolerances for the components of the test fixture produced in U.S. customary units shall be standard tolerances as follows: Unless noted otherwise on the drawings, dimensions given to one decimal place (0.X in.) shall be  $\pm 0.05$  in., dimensions given to two decimal places (0.0X in.) shall be  $\pm 0.01$  in., and dimensions given to three decimal places (0.00X in.) shall be  $\pm 0.005$  in. For components produced in SI units, standard tolerances for dimensions given to zero decimal places (X mm) shall be  $\pm 0.1$

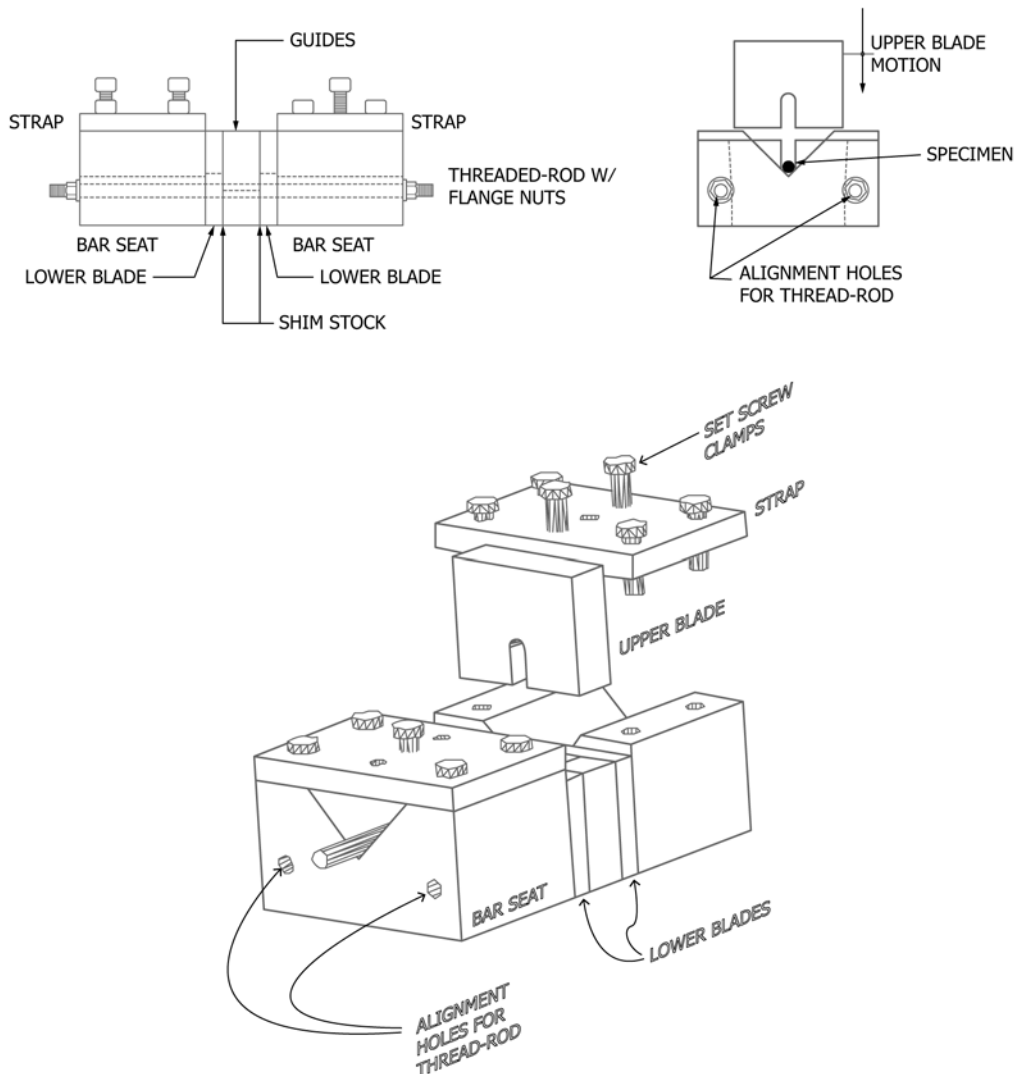
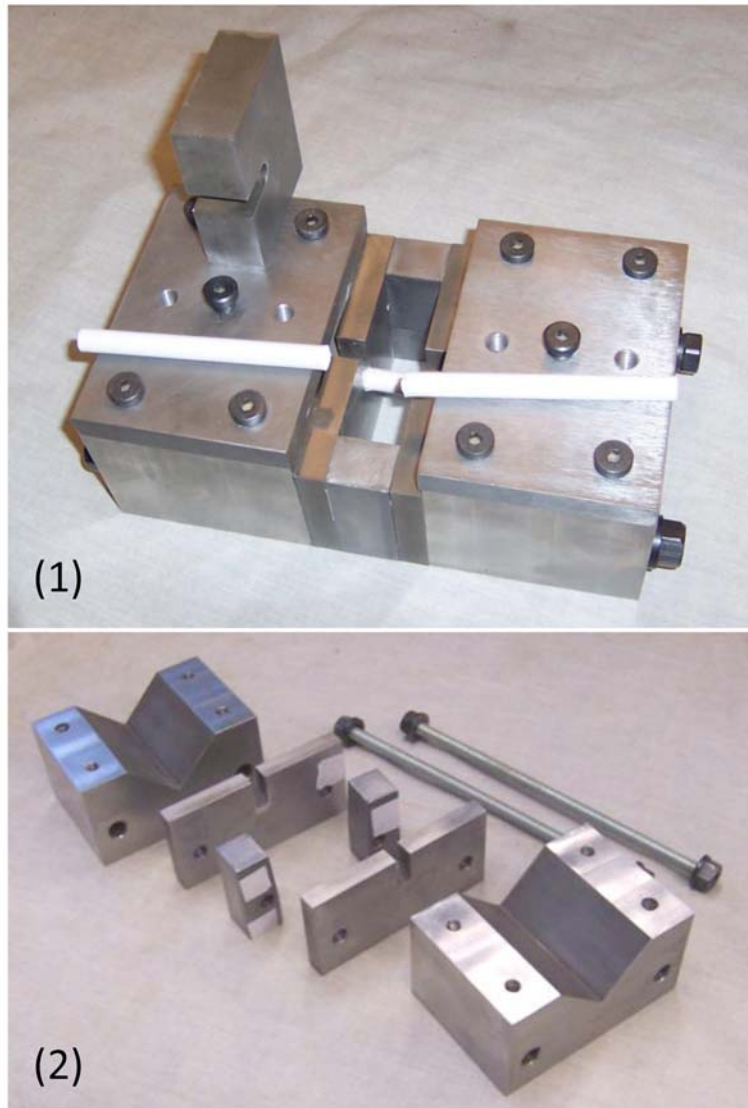


FIG. 2 Transverse Shear Fixture Assembled (Side Views and Axonometric View)



NOTE 1—(1) Assembled fixture with sheared specimen and (2) main body of fixture disassembled (note presence of shim stock on guides).

**FIG. 3 Photographs of Test Fixture**

mm, dimensions given to one decimal place (0.X mm) shall be  $\pm 0.25$  mm, dimension given to two decimal places (0.0X mm) shall be  $\pm 0.10$  mm.

**7.3 Bar Seats**—The two bar seats are identical and have a v-shaped bed for supporting the ends of the bars (see Fig. 4a and b).

**7.4 Blades**—The lower blades and upper blade should be machined from tool steel, hardened to 55 to 58 HRC.

**7.4.1 Lower Blades**—The two lower blades are machined from 12 mm [0.500 in.] thick steel having a precision ground finish of  $0.80 \mu\text{m}$  [32  $\mu\text{in.}$ ] or better. The slots in the lower blades are machined based on the diameter of the bars to be tested. For smooth round rods, the width of the slot shall be 0.10 mm [0.004 in.] wider than the measured diameter of the rods. For textured or undulating bars the slot shall be equal to the projected outer diameter from the roughly circular bar. The depth of the semi-circle at the bottom of the slot shall be

established so that the diameter of the semi-circle is tangent with the angled side of the bar seat (see Fig. 1 and Fig. 5).

**7.4.2 Upper Blade**—The upper blade is machined from 25 mm [1.000 in.] thick steel having a precision ground finish of  $0.80 \mu\text{m}$  [32  $\mu\text{in.}$ ] or better. The upper blade has the same machined slot and diameter as the two lower blades (see Fig. 7a and b).

NOTE 2—This standard does not give specific dimensional requirements for the slots and diameters of the lower and upper blades, as a wide range of textured bars and smooth rods, produced under both SI and US Customary standards, may be tested using this method. Fig. 5 and Fig. 7 depict the dimensions of lower and upper blades for a 3/8 in. and a 10 mm smooth rod. In U.S. practice, blades for the apparatus are typically made for smooth and textured rods in diameters that range between 6 mm (0.25 in.) to 25 mm (1 in.).

**7.5 Guides**—The guides are machined from the same steel as the upper blade. The two guides are of equal thickness to the upper blade and may be tapered to facilitate insertion of the

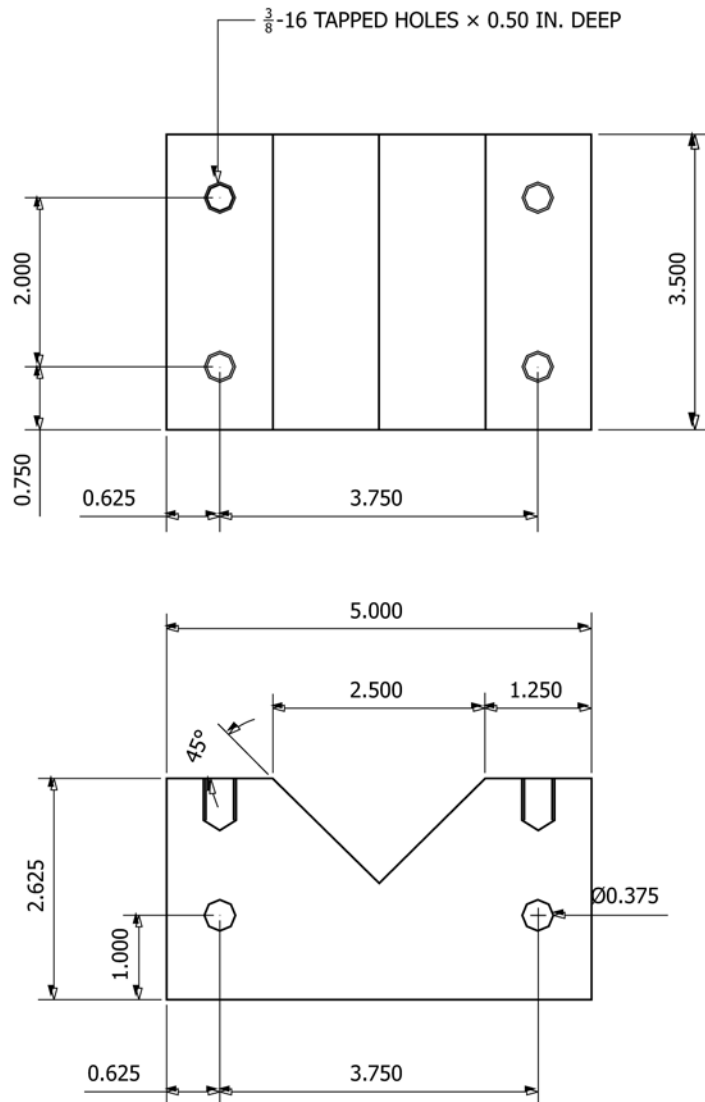


FIG. 4 a Bar Seat (U.S. Customary Units)

upper blade into the fixture. The holes in the guides align with the holes in the lower blades and in the bar seats so that the entire assembly can be bolted together (see Fig. 6a and b).

**7.6 Strap**—Straps, nominally 12 mm [0.5 in.] thick, and mounted at the top of both bar seats, are used to clamp the bar or rod firmly into the bar seats during testing. Socket-head cap screws pass through threads in the straps and clamp the specimens onto the bar seats. (see Fig. 8a and b).

**7.7 Testing Machine**—The testing machine shall be in conformance with Practices E4 and shall satisfy the following requirements:

**7.7.1 Testing Machine Heads**—The testing machine shall have both an essentially stationary head and a movable head. The movable head shall be equipped with a deflection measuring device.

**7.7.2 Drive Mechanism**—The testing machine drive mechanism shall be capable of imparting to the movable head a controlled velocity with respect to the stationary head. The

velocity of the movable head shall be capable of being regulated as specified in 11.4.

**7.7.3 Force Indicator**—The testing machine force-sensing device shall be capable of indicating the total force being carried by the test specimen. This device shall be essentially free from inertia lag at the specified rate of testing and shall indicate the force with an accuracy over the force range(s) of interest of within  $\pm 1\%$  of the indicated value. The force range(s) of interest may be fairly low for modulus evaluation, much higher for strength evaluation, or both, as required.

## 8. Sampling and Test Specimens

**8.1 Specimens** shall be representative of the lot or batch being tested. In the test section of the specimen, no postproduction machining, abrading, or other such processing is permitted.

**8.2 Sampling**—Test at least five specimens per test condition unless valid results can be gained through the use of fewer



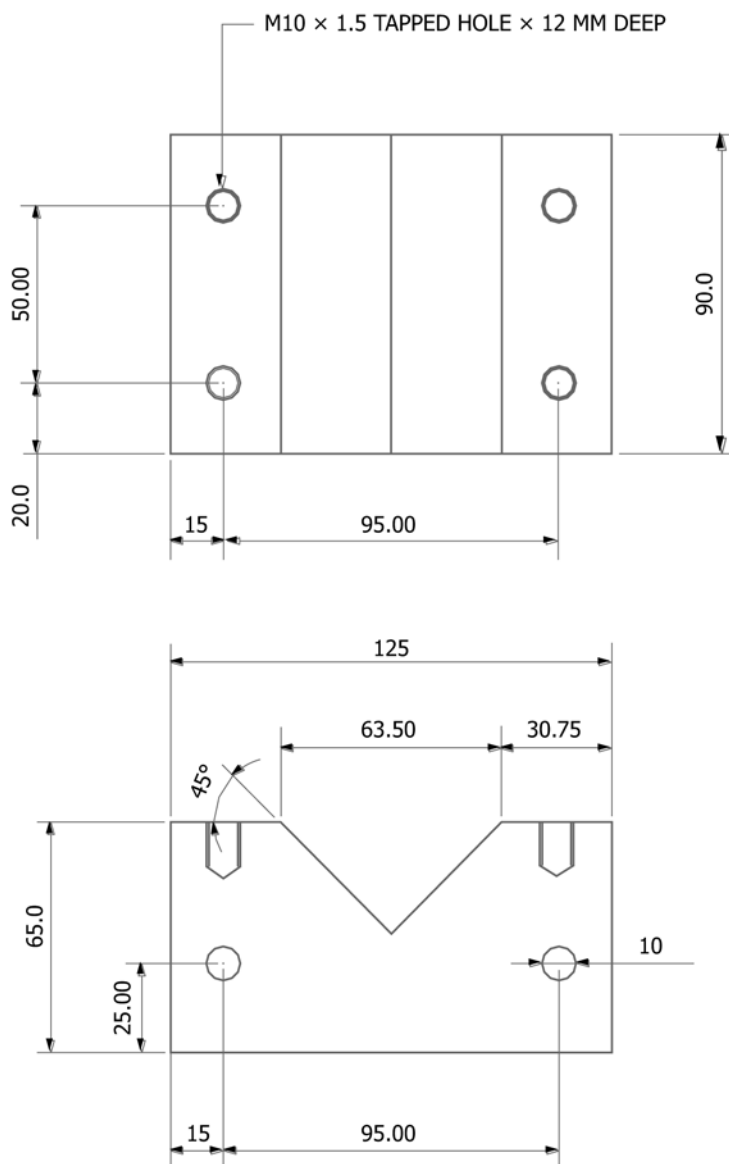


FIG. 4 b Bar Seat (SI Units) (continued)

specimens, such as in the case of a designed experiment. For statistically significant data, the procedures outlined in [E122](#) should be consulted. The method of sampling shall be reported.

8.3 The length of the specimen shall be 225 mm [9 in.].

8.4 The cross sectional area of textured or undulating bars shall be determined in accordance with either of the two methods described in [D7205/D7205M](#): nominal area or standard area. The cross sectional area of smooth round rods shall be determined by measuring the average diameter of the rod to a precision of 0.02 mm [0.001 in.] and calculating the area of the rod assuming that it is circular.

## 9. Calibration

9.1 The accuracy of all measuring equipment shall have certified calibrations that are current at the time of use of the equipment.

## 10. Conditioning

10.1 The recommended pre-test condition is effective moisture equilibrium at a specific relative humidity as established by Test Method [D5229/D5229M](#); however, if the test requestor does not explicitly specify a pre-test conditioning environment, no conditioning is required and the specimens may be tested as prepared.

10.2 The pre-test specimen conditioning process, to include specified environmental exposure levels and resulting moisture content, shall be reported with the test data.

10.3 If no explicit conditioning process is performed the specimen conditioning process shall be reported as “unconditioned” and the moisture content as “unknown.”

NOTE 3—The term moisture, as used in Test Method [D5229/D5229M](#), includes not only the vapor of a liquid and its condensate, but the liquid

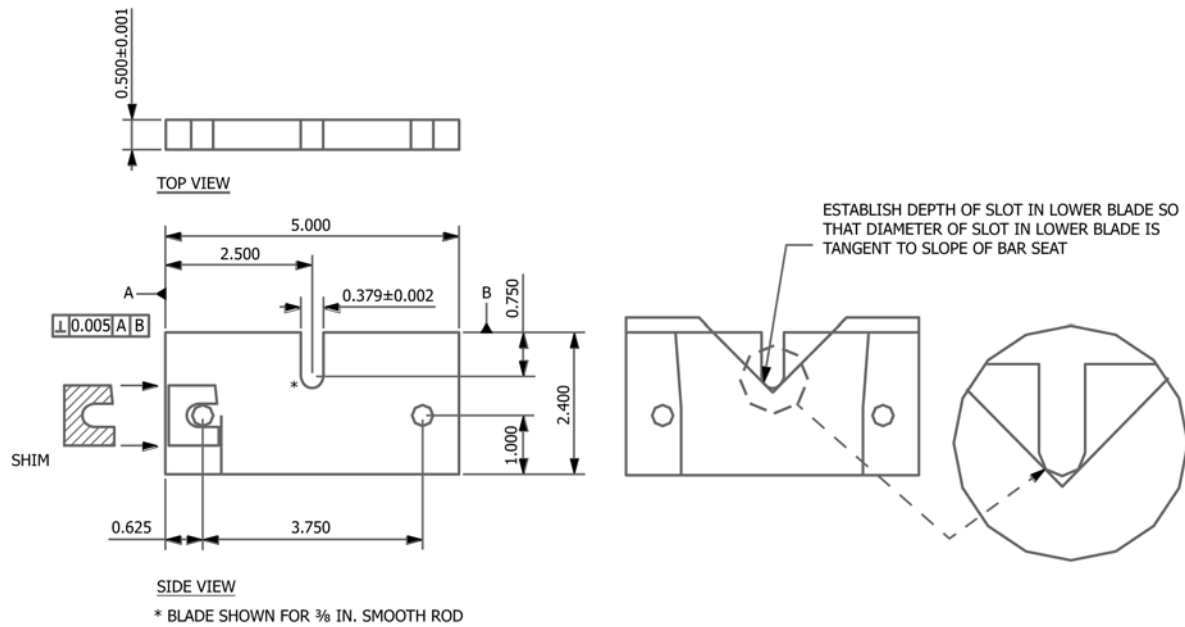


FIG. 5 a Lower Blade for 3/8 in. Diameter Smooth Rod

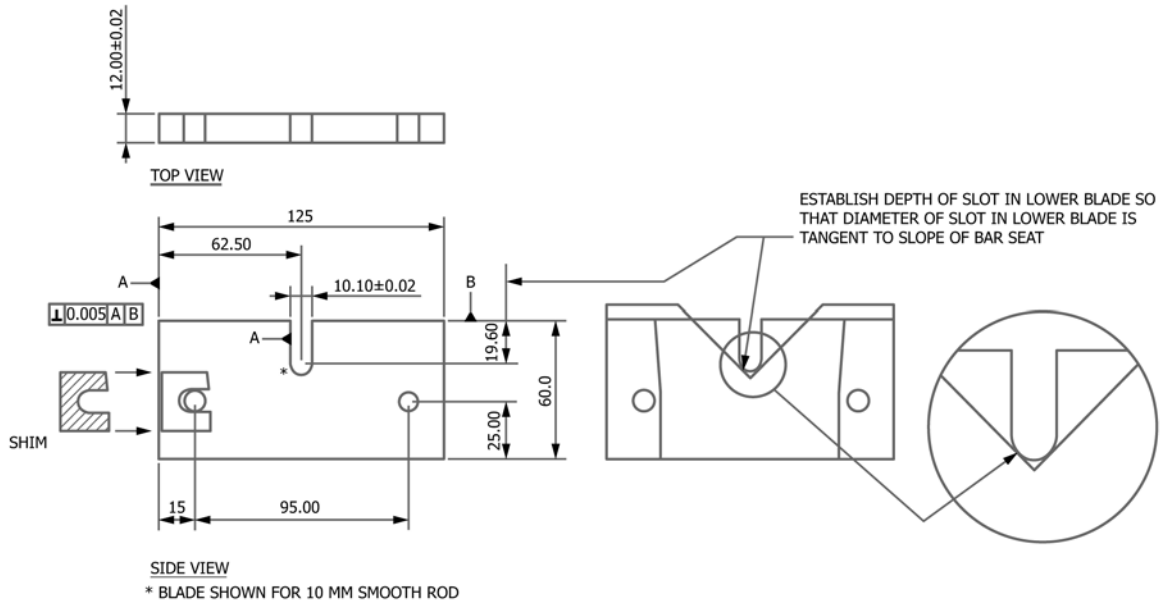


FIG. 5 b Lower Blade for 10 mm Diameter Smooth Rod (continued)

itself in large quantities, as for immersion.

## 11. Procedure

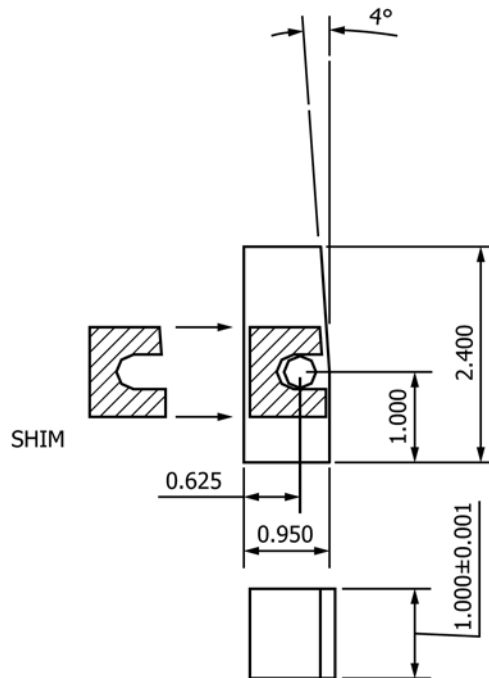
11.1 The specimen shall be centered within the shear apparatus, resting against the bar seats and lower blades.

11.2 Insert and hand-tighten two set screws in one strap so that one end of the bar is clamped by the two screws pressing onto the bar, through the two end holes in the straps. Hand-tighten one set screw in the other strap, through the center hole in this strap, to clamp the opposite end of the bar. If specimens appear to move in the bar seats during testing, or significant

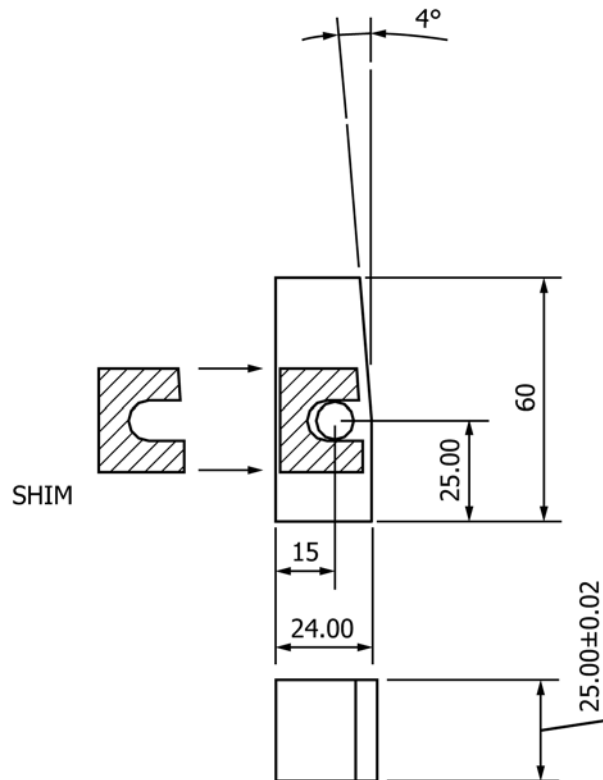
local damage is noted where the set screws meet the bar, additional set screws should be placed before testing. The fixture allows for a maximum of three set screws on each end of the bar.

11.3 Place the upper blade into place onto the bar and center the fixture in the universal testing machine.

11.4 Complete the test with the test machine in displacement control. The displacement rate should be selected so as to produce failure within 1 to 10 min. Force should be applied uniformly without subjecting the specimen to impact.



NOTE 1—Location of optional shims shown (see section 7.1).  
**FIG. 6 a Guides (U.S. Customary Units)**

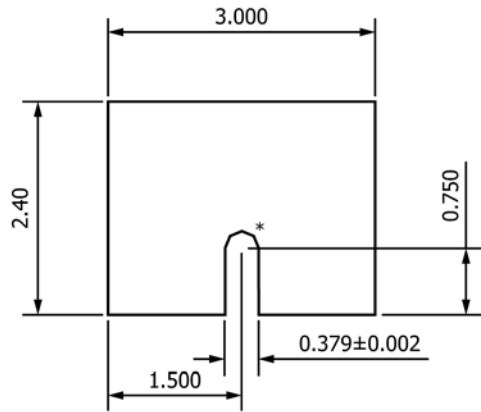


NOTE 1—Location of optional shims shown (see section 7.1).  
**FIG. 6 b Guides (SI Units) (continued)**

11.5 Monitor force versus displacement continuously or at frequent regular intervals. If a transition region or initial failure is noted, record the load at such points.

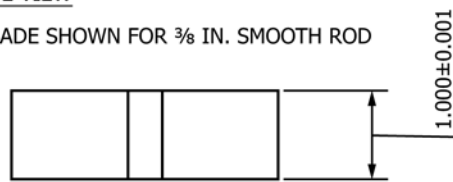
NOTE 4—The test method does not require the reporting of force versus crosshead displacement data, but it is recommended that force and displacement be monitored continuously during the test to (1) establish





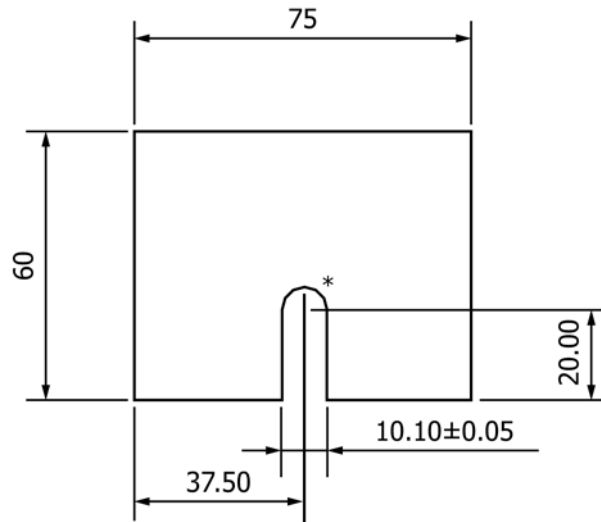
SIDE VIEW

\* BLADE SHOWN FOR  $\frac{3}{8}$  IN. SMOOTH ROD



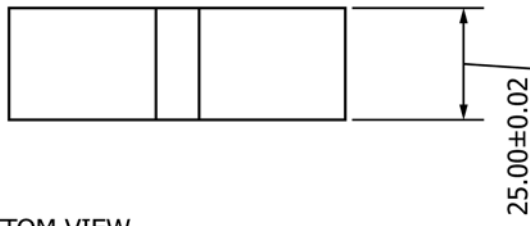
BOTTOM VIEW

FIG. 7 a Upper Blade for  $\frac{3}{8}$  in. Diameter Smooth Rod (U.S. Customary Units)



SIDE VIEW

\* BLADE SHOWN FOR 10 MM SMOOTH ROD



BOTTOM VIEW

FIG. 7 b Upper Blade for 10 mm Diameter Smooth Rod (SI Units) (continued)

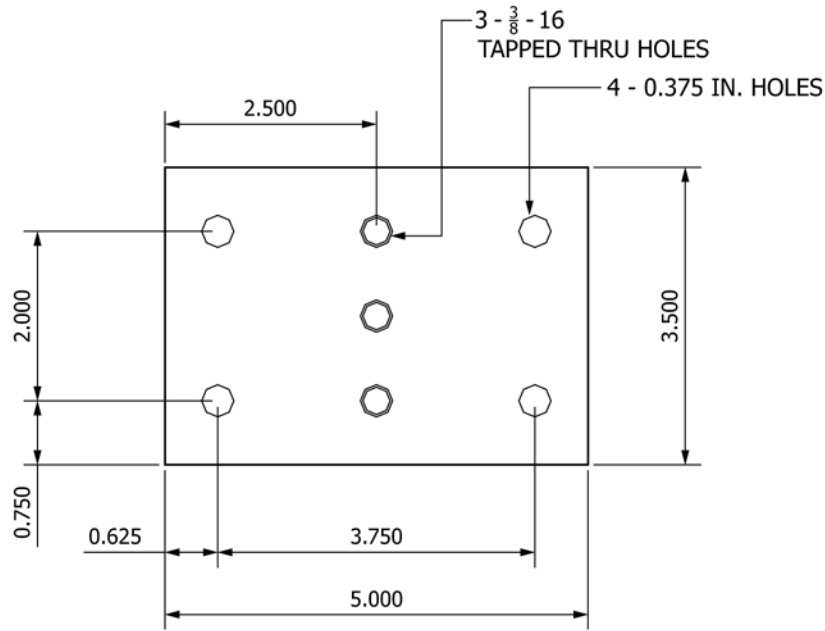


FIG. 8 a Straps (U.S. Customary Units)

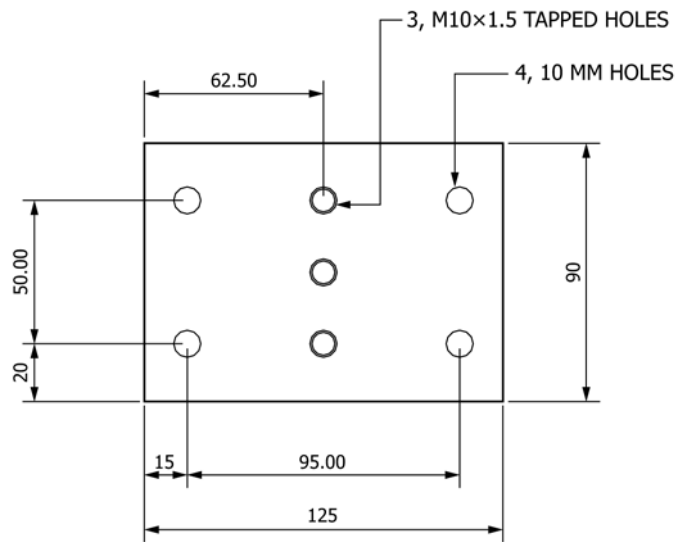


FIG. 8 b Straps (SI Units) (continued)

proper displacement rates for a given specimen size, (2) identify the formation of failure surfaces during the test (see Fig. 9), (3) establish that the peak loading has been observed in accordance with the requirements of section 11.6, and (4) assist in troubleshooting.

11.6 Loading shall be continued until the specimen fails (see Fig. 3). The failure force should be recorded with a precision to three significant digits. The force may drop slightly and the stiffness of the specimen may change at the onset of failure, due to the delay in the formation of the second failure face (see Note 1 in Fig. 9). Continue loading the specimen until the second failure face forms or the force has dropped to 70 % of the observed peak force. (see Notes 2 and 3 in Fig. 9).

## 12. Calculations

12.1 Transverse shear strength shall be calculated according to Eq 1, with a precision to three significant digits,

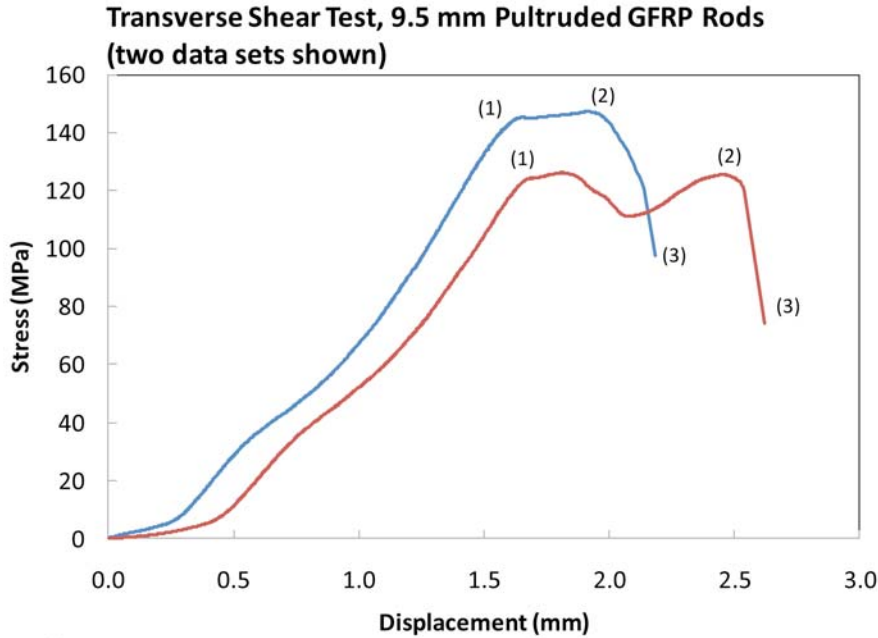
$$\tau_U = \frac{P_S}{2A} \quad (1)$$

where:

$\tau_U$  = transverse shear strength, MPa [psi]

$P_S$  = maximum failure force, N [lbf]

$A$  = cross sectional area of specimen, mm<sup>2</sup>[in.<sup>2</sup>] determined according to section 8.4



Notes:

- (1) Apparent stiffness of specimen will drop when first shearing face forms.
- (2) Continue test until second shearing face is fully formed and peak force is achieved.
- (3) Do not discontinue test until load drops to below 70% of observed peak load.

**FIG. 9 Example Shear Stress versus Crosshead Displacement Graph**

12.2 *Statistics*—For each series of tests calculate the average, standard deviation and coefficient of variation (in percent) of the transverse shear strength as follows:

$$\bar{x} = \left( \sum_{i=1}^n x_i \right) / n \quad (2)$$

$$S_{n-1} = \sqrt{\left( \sum_{i=1}^n x_i^2 - n\bar{x}^2 \right) / (n-1)} \quad (3)$$

$$CV = 100 \times S_{n-1} / \bar{x} \quad (4)$$

where:

- $\bar{x}$  = sample mean (average),
- $S_{n-1}$  = sample standard deviation,
- $V$  = sample coefficient of variation, %,
- $n$  = number of specimens, and
- $x_i$  = measured or derived property.

### 13. Validation

13.1 Values for shear strength shall not be calculated for any specimen that fails away from the two shearing planes. Retests shall be performed for any specimen on which values are not calculated.

### 14. Report

14.1 Report the following information, or references pointing to other documentation containing this information, to the maximum extent applicable (reporting of items beyond the control of a given testing laboratory, such as might occur with

material details or bar fabrication parameters, shall be the responsibility of the requestor):

14.1.1 The revision level or date of issue of this test method.

14.1.2 The date(s) and location(s) of the test.

14.1.3 The name(s) of the test operator(s).

14.1.4 Any variations to this test method, anomalies noticed during testing or equipment problems occurring during testing.

14.1.5 Identification of the material tested including (if available) : material specification, material type, material designation, manufacturer, manufacturer's lot or batch number, source (if not from manufacturer), date of certification, expiration of certification, filament diameter, tow or yarn filament count and twist, sizing, form or weave, and matrix type.

14.1.6 If available, description of the fabrication steps used to prepare the bar including fabrication start date, fabrication end date, process specification, cure cycle, consolidation method, and a description of the equipment used.

14.1.7 Description of surface characteristics of the bar. Indicate the representative length of the bar, if appropriate.

14.1.8 If requested, report density, volume percent reinforcement, and void content test methods, specimen sampling method and geometries, test parameters, and test results.

14.1.9 For textured or undulating bars, average value of the nominal area of the bar and the projected bar diameter.

14.1.10 Slot width and diameter of the upper and lower blades.

14.1.11 Results of any nondestructive evaluation tests.



14.1.12 Method of preparing the test specimen, including specimen labeling scheme and method, specimen geometry, sampling method, and bar cutting method.

14.1.13 Calibration dates and methods for all measurement and test equipment.

14.1.14 Type of test machine, control strategy, displacement rate, and data acquisition sampling rate and equipment type if applicable.

14.1.15 Conditioning parameters and results, use of travelers and traveler geometry, and the procedure used, if other than that specified in the test method.

14.1.16 Environment of the test machine environmental chamber (if used).

14.1.17 Number of specimens tested.

14.1.18 Type of area values used for stress calculation: nominal area or standard area. Calculation method for nominal

area (if used), in accordance with **D7205/D7205M** or by measurement. Specimen diameter if measured.

14.1.19 Maximum force and shear stress for each specimen.

## 15. Precision and Bias

15.1 *Precision*—The data required for the development of a precision statement is not available for this test method. Precision, defined as the degree of mutual agreement between individual measurements, cannot yet be estimated because of an insufficient amount of data.

15.2 *Bias*—Bias cannot be determined for this test method as no acceptable reference standard exists.

## 16. Keywords

16.1 bars; composite bars; composite materials; double shear; rebar; reinforcing bars; shear properties; shear strength

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