Designation: D7565/D7565M – 09

Standard Test Method for Determining Tensile Properties of Fiber Reinforced Polymer Matrix Composites Used for Strengthening of Civil Structures[1]

This standard is issued under the fixed designation D7565/D7565M; 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 the requirements for sample preparation, tensile testing, and results calculation of flat fiber reinforced polymer (FRP) composite materials used for the strengthening of structures made of materials such as metals, timber, masonry, and reinforced concrete. The method may be used to determine the tensile properties of wet lay-up and pre-impregnated FRP composites fabricated on site or manufactured in a factory setting. The FRP composite may be of either unidirectional (0-degrees) or cross-ply (0/90 type) reinforcement. For cross-ply laminates, the construction may be achieved using multiple-layers of unidirectional fibers at either 0 or 90 degrees, or one or more layers of stitched or woven 0/90 fabrics. The composite material forms are limited to continuous fiber or discontinuous fiber-reinforced composites in which the laminate is balanced and symmetric with respect to the test direction. The method only covers the determination of the tensile properties of the FRP composite material. Other components used to attach the FRP material to the substrate, such as the primer, putty, and adhesive in externally bonded strengthening systems, are excluded from the sample preparation and testing detailed in this document. This test method refers to Test Method D3039/D3039M for conduct of the tests.

1.2 The values stated in either SI units or inch-pound units are to be regarded as standard. Within the text, the inch-pound units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

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]

D883 Terminology Relating to Plastics

D3039/D3039M Test Method for Tensile Properties of Polymer Matrix Composite Materials

D3878 Terminology for Composite Materials

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

D5687/D5687M Guide for Preparation of Flat Composite Panels with Processing Guidelines for Specimen Preparation

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

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

E456 Terminology Relating to Quality and Statistics

3. Terminology

3.1 *Definitions*—Terminology D3878 defines terms relating to high-modulus fibers and their composites. Terminology D883 defines terms relating to plastics. Terminology E6 defines terms relating to mechanical testing. Terminology E456 and E177 define terms relating to statistics. In the event of a conflict between terms, Terminology D3878 shall have precedence over the other standards.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *screed*, *v*—to move a flat rule along the top of a saturated laminate to level the top of the laminate and simultaneously remove excess resin.

3.2.2 *shop-manufactured FRP composite*, *n*—an FRP composite material manufactured under controlled conditions using an automated process in a factory, typically with tight control

[1] This test method is under the jurisdiction of ASTM Committee D30 on Composite Materials and is the direct responsibility of Subcommittee D30.05 on Structural Test Methods.

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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.

over the volume fractions and alignment of fibers, matrix, and voids in the material as well as the cross-sectional geometry. For strengthening applications, shop-manufactured FRP composites are typically bonded to the substrate subsequent to the fabrication of the composite reinforcement..

3.2.3 *wet lay-up FRP composite*, *n*—an FRP composite material fabricated by manually impregnating dry fibers with a matrix of polymeric resin. Semi-automated processes such as machine-aided wetting of fabrics before placement or vacuum-aided impregnation of laminates after placement are considered part of wet lay-up FRP. For civil infrastructure strengthening applications, the degree of control over the volume fractions of fibers, matrix, and voids as well as the overall cross-sectional geometry in wet lay-up FRP composites may be less than that for shop-manufactured composites on account of the manual process. For strengthening applications, wet lay-up FRP composites are typically applied to the substrate at the same time the dry fiber is impregnated. The impregnating resin acts as the saturant for the FRP composite and as the bonding agent between the composite reinforcement and the substrate. Wet lay-up specimens may be fabricated in either a field or a laboratory setting.

3.3 *Symbols:*

3.3.1 *CV*—sample coefficient of variation.

3.3.2 F^{*}—force carrying capacity of FRP laminate per unit width.

3.3.3 K^{*}—stiffness of FRP laminate per unit width.

3.3.4 L_g—extensometer gage length.

3.3.5 *n*—number of specimens.

3.3.6 *P*—force carried by test coupon.

3.3.7 P^{max}—maximum tensile force.

3.3.8 s_{n-1}—sample standard deviation.

3.3.9 *w*—coupon width.

3.3.10 x_I—test result for an individual coupon from the sample population for a given property.

3.3.11 $\bar{x}$—mean or average (estimate of mean) of a sample population for a given property.

3.3.12 σ—normal stress.

4. Summary of Test Method

4.1 Flat FRP specimens are prepared using a wet lay-up fabrication procedure or cut from a shop-manufactured laminate. For testing purposes, wet lay-up material may be prepared in a laboratory or field setting, as the testing objectives dictate. The testing of the specimens is carried out according to the provisions of Test Method D3039/D3039M. The ultimate force per unit width of the material is determined from the maximum force carried before failure. If the load-strain response of the material is monitored with strain gages or extensometers, then the stiffness of the material per unit width and the ultimate tensile strain of the material may be determined.

5. Significance and Use

5.1 This test method can be used to obtain the tensile force capacity and ultimate tensile strain of FRP material used for the strengthening of other structural materials such as, metals, timber, and reinforced concrete. The principal test variables could be the FRP constituents and fabrication method or the size or type of FRP laminate. The obtained tensile properties can be used for material specifications, quality control and assurance, structural design and analysis, and research and development. The stress, strength, and modulus of elasticity can be calculated using either the gross composite area method or the effective fiber area method.

5.2 This test method focuses on the FRP material itself, irrespective of the gripping method. Therefore, maximum force and strain data associated with failure or pullout at either grip are disregarded. The force capacity and maximum strain measurements are based solely on test specimens that fail in the gauge section.

6. Interferences

6.1 A summary of the interferences, specifically material and specimen preparation, gripping, system alignment, and edge effects are presented in D3039/D3039M.

6.2 Additional interferences may arise from lack of control in wet lay-up specimen preparation procedures outlined in 8.3.1. Specimen variations in resin content, ply thickness, void content and degree of cure may contribute to variability in test results.

7. Apparatus

7.1 Requirements for testing machines and instrumentation are the same as those given in D3039/D3039M, Section 7.

8. Sampling and Test Specimens

8.1 *Sampling*—Test at least five specimens per test condition unless valid results can be gained through the use of fewer specimens, such as in the case of a designed experiment. For statistically significant data, the procedures outlined in Practice E122 should be consulted. Report the method of sampling.

NOTE 1—If specimens are to undergo environmental conditioning to equilibrium, and are of such type or geometry that the weight change of the material cannot be properly measured by weighing the specimen itself (such as a tabbed mechanical coupon), then use another traveler coupon of the size (but without tabs) to determine when equilibrium has been reached for the specimens being conditioned.

8.2 *Geometry*—Variation in specimen width should be no greater than ±1%. Specimens width should be determined per Test Method D3039/D3039M, Section 7.1. Other dimensions shall conform to Test Method D3039/D3039M Section 8.2.1 with the exception of thickness, which is not required to be measured. Specimen thickness may however be measured as part of the general characterization of the specimen, and should be reported if measured.

NOTE 2—Calculations according to this method are based on force per unit coupon width and stiffness per unit coupon width. Specimen thickness is not required for these calculations.

8.2.1 *Specimen Width*—Minimum specimen width for unidirectional shop-manufactured and wet lay-up FRP specimens shall be 25 mm [1.0 in.]. Minimum width for cross-ply specimens shall be 25 mm [1.0 in.] for shop-manufactured composites and 38 mm [1.5 in.] for wet lay-up composites.

NOTE 3—For both unidirectional and cross-ply laminates, where fibers are used in large bundles (i.e, rovings, tows) that will be wider than 3 mm [0.12 in.] when laid into the laminate, it is recommended that a specimen width of 38 mm [1.5 in.] or higher be used.