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## Standard Guide for Testing Fabric-Reinforced “Textile” Composite Materials<sup>1</sup>

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### INTRODUCTION

A variety of fabric-reinforced composite materials have been developed for use in aerospace, automotive, civil, construction, and other applications. These composite materials are reinforced with continuous fiber yarns that are formed into two-dimensional or three-dimensional fabrics. Various fabric constructions, such as woven, braided, stitched, and so forth, can be used to form the fabric reinforcement. Due to the nature of the reinforcement, these materials are often referred to as “textile” composites.

Textile composites can be fabricated from 2-dimensional (2-D) or 3-dimensional (3-D) fabrics. Stitched preforms and 3-D fabrics contain through-thickness yarns, which can lead to greater delamination resistance. Textile composites are also amenable to automated fabrication. However, the microstructure (or fiber architecture) of a textile composite, which consists of interlacing yarns, can lead to increased inhomogeneity of the local displacement fields in the laminate. Depending upon the size of the yarns and the pattern of the weave or braid, the inhomogeneity within a textile composite can be large compared to traditional tape laminates.

Thus, special care should be exercised in the use of the current ASTM standards developed for high performance composites. In many cases, the current ASTM standards are quite adequate if proper attention is given to the special testing considerations for textile composites covered in this guide. However, in some cases, current standards do not meet the needs for testing of the required properties. This guide is intended to increase the user’s awareness of the special considerations necessary for the testing of these materials. It also provides the user with recommended ASTM standards that are applicable for evaluating textile composites. The specific properties for which current ASTM standards might not apply are also highlighted in this guide.

### 1. Scope

1.1 This guide is applicable to the testing of textile composites fabricated using fabric preforms, such as weaves, braids, stitched preforms, and so forth, as the reinforcement. The purpose of this guide is to:

1.1.1 Ensure that proper consideration is given to the unique characteristics of these materials in testing.

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<sup>1</sup> This guide is under the jurisdiction of ASTM Committee D30 on Composite Materials and is the direct responsibility of Subcommittee D30.04 on Lamina and Laminate Test Methods.

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1.1.2 Assist the user in selecting the best currently available ASTM test method for the measurement of commonly evaluated material properties for this class of materials.

1.2 Areas where current ASTM test methods do not meet the needs for testing of textile composites are indicated.

1.3 It is not the intent of this guide to cover all test methods which could possibly be used for textile composites. Only the most commonly used and most applicable standards are included.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be

used independently of the other, and values from the two systems shall not be combined.

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

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 requirements 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:<sup>2</sup>

- D792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
- D883 Terminology Relating to Plastics
- D2344/D2344M Test Method for Short-Beam Strength of Polymer Matrix Composite Materials and Their Laminates
- D3039/D3039M Test Method for Tensile Properties of Polymer Matrix Composite Materials
- D3171 Test Methods for Constituent Content of Composite Materials
- D3410/D3410M Test Method for Compressive Properties of Polymer Matrix Composite Materials with Unsupported Gage Section by Shear Loading
- D3479/D3479M Test Method for Tension-Tension Fatigue of Polymer Matrix Composite Materials
- D3518/D3518M Test Method for In-Plane Shear Response of Polymer Matrix Composite Materials by Tensile Test of a  $\pm 45^\circ$  Laminate
- D3846 Test Method for In-Plane Shear Strength of Reinforced Plastics
- D3878 Terminology for Composite Materials
- D4255/D4255M Test Method for In-Plane Shear Properties of Polymer Matrix Composite Materials by the Rail Shear Method
- D5229/D5229M Test Method for Moisture Absorption Properties and Equilibrium Conditioning of Polymer Matrix Composite Materials
- D5379/D5379M Test Method for Shear Properties of Composite Materials by the V-Notched Beam Method
- D5528 Test Method for Mode I Interlaminar Fracture Toughness of Unidirectional Fiber-Reinforced Polymer Matrix Composites
- D5687/D5687M Guide for Preparation of Flat Composite Panels with Processing Guidelines for Specimen Preparation
- D5766/D5766M Test Method for Open-Hole Tensile

- Strength of Polymer Matrix Composite Laminates
  - D5961/D5961M Test Method for Bearing Response of Polymer Matrix Composite Laminates
  - D6115 Test Method for Mode I Fatigue Delamination Growth Onset of Unidirectional Fiber-Reinforced Polymer Matrix Composites
  - D6415/D6415M Test Method for Measuring the Curved Beam Strength of a Fiber-Reinforced Polymer-Matrix Composite
  - D6484/D6484M Test Method for Open-Hole Compressive Strength of Polymer Matrix Composite Laminates
  - D6641/D6641M Test Method for Compressive Properties of Polymer Matrix Composite Materials Using a Combined Loading Compression (CLC) Test Fixture
  - D6671/D6671M Test Method for Mixed Mode I-Mode II Interlaminar Fracture Toughness of Unidirectional Fiber Reinforced Polymer Matrix Composites
  - D7078/D7078M Test Method for Shear Properties of Composite Materials by V-Notched Rail Shear Method
  - D7264/D7264M Test Method for Flexural Properties of Polymer Matrix Composite Materials
  - D7291/D7291M Test Method for Through-Thickness “Flatwise” Tensile Strength and Elastic Modulus of a Fiber-Reinforced Polymer Matrix Composite Material
  - D7774 Test Method for Flexural Fatigue Properties of Plastics
  - E6 Terminology Relating to Methods of Mechanical Testing
  - E83 Practice for Verification and Classification of Extensometer Systems
  - E122 Practice for Calculating Sample Size to Estimate, With Specified Precision, the Average for a Characteristic of a Lot or Process
  - E251 Test Methods for Performance Characteristics of Metallic Bonded Resistance Strain Gages
  - E456 Terminology Relating to Quality and Statistics
  - E1237 Guide for Installing Bonded Resistance Strain Gages
- 2.2 *Other Standards:*
- ISO 19927 Fibre-reinforced plastic composites – Determination of interlaminar strength and modulus by double beam shear test

## 3. Terminology

3.1 *Definitions*—Definitions used in this guide are defined by various ASTM methods. 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** defines terms relating to statistics. In the event of a conflict between definitions of terms, Terminology **D3878** shall have precedence over the other standards. Terms relating specifically to textile composites are defined by Ref **(1)**.<sup>3</sup>

3.2 *textile unit cell*—In theory, textile composites have a repeating geometrical pattern based on manufacturing parameters. This repeating pattern is often referred to as the material’s “unit cell.” It is defined as the smallest section of

<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.

<sup>3</sup> The boldface numbers in parentheses refer to the list of references at the end of this standard.

architecture required to repeat the textile pattern (see Figs. 1-4). Handling and processing can distort the “theoretical” unit cell. Parameters such as yarn size, yarn spacing, fabric construction, and fiber angle may be used to calculate theoretical unit cell dimensions. However, several different “unit cells” may be defined for a given textile architecture. For example, Fig. 2 shows two different unit cells for the braided architectures. Thus, unit cell definition can be somewhat subjective based on varying interpretations of the textile architecture. The user is referred to Refs (1, 2) for further guidance. In this guide, to be consistent, the term “unit cell” is used to refer to the smallest unit cell for a given textile architecture. This smallest unit cell is defined as the smallest section of the textile architecture required to replicate the textile pattern by using only in-plane translations (and no rotations) of the unit cell. Examples of the smallest unit cells for some of the commonly used textile composites are shown in Figs. 1-4. For the 3-D weaves in Figs. 3 and 4, the smallest unit cell length (as indicated) is defined by the undulating pattern of the warp yarns. The smallest unit cell width is the distance between two adjacent warp stuffer yarn columns (in the fill yarn direction) and the smallest unit cell height is the consolidated woven composite thickness.

**4. Significance and Use**

4.1 This guide is intended to serve as a reference for the testing of textile composite materials.

4.2 The use of this guide ensures that proper consideration is given to the unique characteristics of these materials in testing. In addition, this guide also assists the user in selecting the best currently available ASTM test method for measurement of commonly evaluated material properties.

**5. Summary of Guide**

5.1 Special testing considerations unique to textile composites are identified and discussed. Recommendations for handling these considerations are provided. Special considerations

covered are included in Section 7 on Material Definition; Section 8 on Gage Selection; Section 9 on Sampling and Test Specimens; Section 10 on Test Specimen Conditioning; Section 11 on Report of Results; and Section 12 on Recommended Test Methods.

5.2 Recommended ASTM test methods applicable to textile composites and any special considerations are provided in Section 12 for mechanical and physical properties. Section 13 identifies areas where revised or new standards are needed for textile composites.

**6. Procedure for Use**

6.1 Review Sections 7 – 12 to become familiar with the special testing considerations for textile composites.

6.2 Follow the recommended ASTM test method identified in Section 12 for determining a required property but refer back to this guide for recommendations on test specimen geometry, strain measurement, and reporting of results.

**7. Material Definition**

7.1 *Constituent Definition*—Variations in type and amount of sizing on the fibers can significantly influence fabric quality and subsequently material property test results. Each constituent, that is, the fiber, fiber sizing type and amount, and resin should be carefully documented prior to testing to avoid misinterpretation of test results.

7.1.1 Fiber and resin content should be measured and recorded using at least one unit cell of the material from at least one location in each panel from which test specimens are machined. Section 12 covers methods for measuring these values.

7.1.2 The following items should be documented each time a material is tested: fiber type, fiber diameter, fiber surface treatment or sizing type and amount, and resin type.

7.2 *Fabric Definition*—Due to the limitless possibilities involved in placing yarns during the weaving and braiding

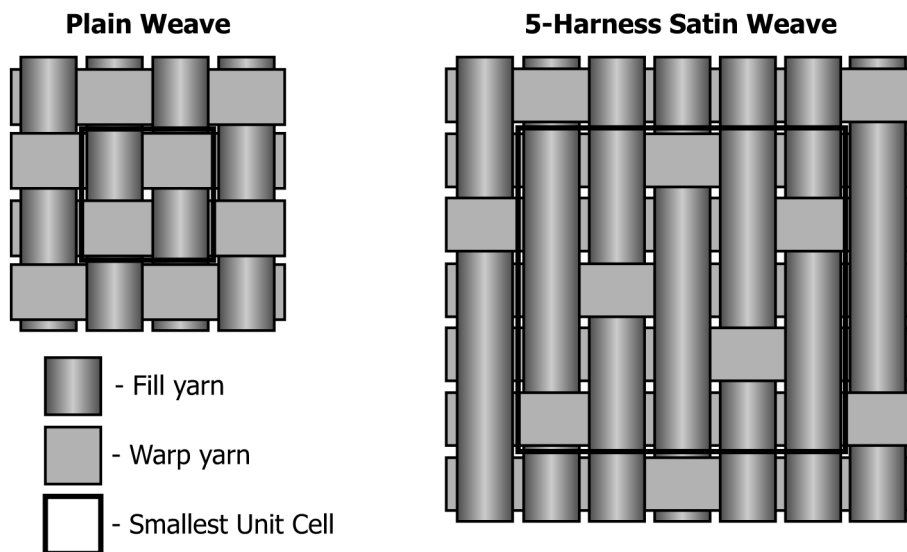


FIG. 1 Smallest Unit Cells for Plain Weave and 5-Harness Satin Weave Architectures