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Standard Guide for Testing Fabric-Reinforced "Textile" Composite Materials[1]

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ε1 NOTE—Editorially changed to a combined standard in September 2010.

INTRODUCTION

A variety of fabric-reinforced composite materials have been developed for use in aerospace, automotive, 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.

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 may not be exact equivalents; therefore, each

[1] 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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system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the 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 and health practices and determine the applicability of regulatory requirements prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D790 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
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 ±45° 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
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 Test Method for Measuring the Curved Beam Strength of a Fiber-Reinforced Polymer-Matrix Composite
D6272 Test Method for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials by Four-Point Bending
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
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
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

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**).[3]

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 materials "unit cell." It is defined as the smallest section of 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

[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 boldface numbers in parentheses refer to the list of references at the end of this standard.

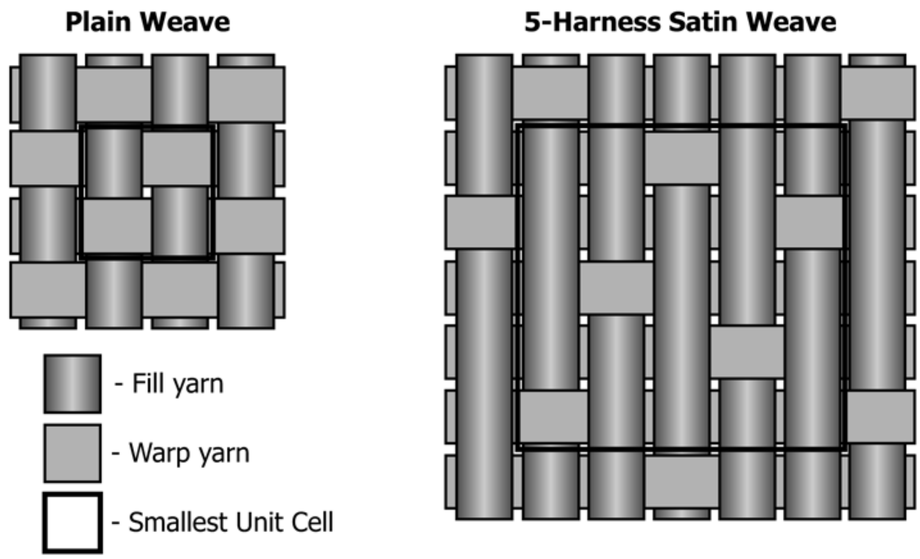

FIG. 1 Smallest Unit Cells for Plain Weave and 5-Harness Satin Weave Architectures

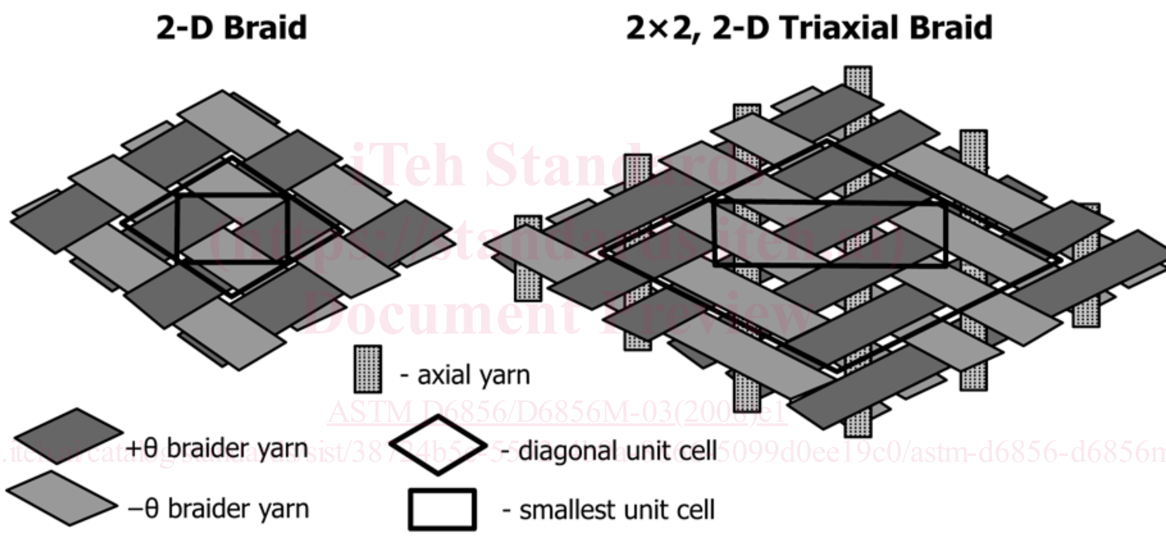

FIG. 2 Smallest Unit Cells for a 2-D Braid and a 2×2, 2-D Triaxial Braid

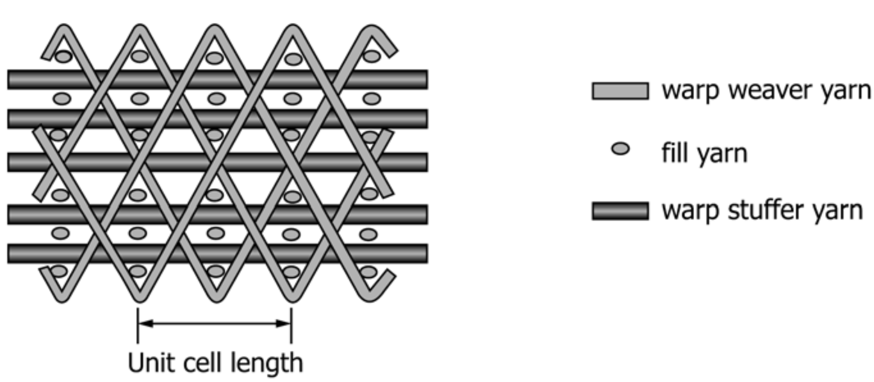

FIG. 3 Smallest Unit Cell Length for Through-Thickness Angle-Interlock Weave

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.

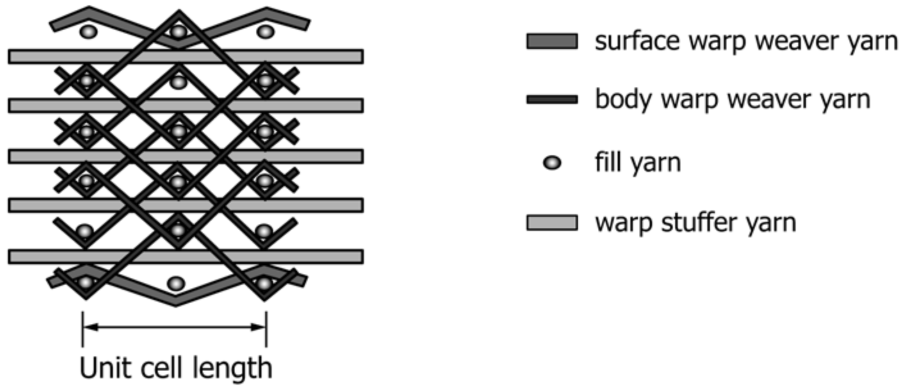

FIG. 4 Smallest Unit Cell Length for Layer-to-Layer Angle-Interlock Weave

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 operations, it is important to carefully document the yarn counts (or yarn sizes), yarn spacings, yarn orientations, yarn contents, weave or braid pattern identification, and yarn interlocking through the preform thickness. Such documentation is required to properly define the textile unit cell and also to properly identify the textile material that was tested and to avoid any possible misinterpretations of the test results.

7.3 *Process Definition*—Processing techniques can affect fiber orientation, void content, and state of polymerization. These factors can in turn influence material property test results significantly. Each of these items should be defined and documented prior to testing to avoid misinterpretation of the test results.

7.3.1 The amount of debulking of the preform during processing can affect the fiber volume and also the fiber orientation through the thickness. In-plane fiber orientation can be adversely affected during the placement of the preform in the mold. Both overall and local variations in fiber orientation should be documented.

7.3.2 As a minimum the following process conditions should be documented for each material tested: preform thickness, preform tackifier (or resin compatible binder) used, molding technique, molding temperature, molding pressure, molding time, and panel dimensions.

8. Strain Gage Selection

8.1 The surface preparation, gage installation, lead wire connection, and verification check procedures described in Test Methods E251 and Guide E1237 are applicable to textile composites and should be used in the application of bonded resistance strain gages.

8.2 The strain gage size selected for each particular textile composite should take into consideration the size of the unit cell for the particular textile composite architecture. Each