Designation: C 297/C 297M – 04

Standard Test Method for Flatwise Tensile Strength of Sandwich Constructions[1]

This standard is issued under the fixed designation C 297/C 297M; 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.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This test method determines the flatwise tensile strength of the core, the core-to-facing bond, or the facing of an assembled sandwich panel. Permissible core material forms include those with continuous bonding surfaces (such as balsa wood and foams) as well as those with discontinuous bonding surfaces (such as honeycomb).

1.2 The values stated in either SI units or inch-pound units are to be regarded separately 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]

C 274 Terminology of Structural Sandwich Constructions
D 792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
D 883 Terminology Relating to Plastics
D 2584 Test Method for Ignition Loss of Cured Reinforced Resins
D 2734 Test Method for Void Content of Reinforced Plastics
D 3039/D 3039M Test Method for Tensile Properties of Polymer Matrix Composite Materials
D 3171 Test Method for Constituent Content of Composite Materials
D 3878 Terminology for Composite Materials
D 5229/D 5229M Test Method for Moisture Absorption Properties and Equilibrium Conditioning of Polymer Matrix Composite Materials
E 4 Practices for Force Verification of Testing Machines
E 6 Terminology Relating to Methods of Mechanical Testing
E 122 Practice for Choice of Sample Size to Estimate a Measure of Quality for a Lot or Process
E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods
E 456 Terminology Relating to Quality and Statistics
E 1309 Guide for Identification of Fiber-Reinforced Polymer-Matrix Composite Materials in Databases
E 1434 Guide for Recording Mechanical Test Data of Fiber-Reinforced Composite Materials in Databases
E 1471 Guide for Identification of Fibers, Fillers, and Core Materials in Computerized Material Property Databases

3. Terminology

3.1 *Definitions*—Terminology D 3878 defines terms relating to high-modulus fibers and their composites. Terminology C 274 defines terms relating to structural sandwich constructions. Terminology D 883 defines terms relating to plastics. Terminology E 6 defines terms relating to mechanical testing. Terminology E 456 and Practice E 177 define terms relating to statistics. In the event of a conflict between terms, Terminology D 3878 shall have precedence over the other terminologies.

3.2 *Symbols*:

A = cross-sectional area of a test specimen

CV = coefficient of variation statistic of a sample population for a given property (in percent)

[1] This test method is under the jurisdiction of ASTM Committee D30 on Composite Materials and is the direct responsibility of Subcommittee D30.09 on Sandwich Construction.

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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.

F_z^{ftu} = ultimate flatwise tensile strength

P_{max} = maximum force carried by test specimen before failure

S_{n-1} = standard deviation statistic of a sample population for a given property

x_1 = test result for an individual specimen from the sample population for a given property

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

4. Summary of Test Method

4.1 This test method consists of subjecting a sandwich construction to a uniaxial tensile force normal to the plane of the sandwich. The force is transmitted to the sandwich through thick loading blocks, which are bonded to the sandwich facings or directly to the core.

4.2 The only acceptable failure modes for flatwise tensile strength are those which are internal to the sandwich construction. Failure of the loading block-to-sandwich bond is not an acceptable failure mode.

5. Significance and Use

5.1 In a sandwich panel, core-to-facing bond integrity is necessary to maintain facing stability and permit load transfer between the facings and core. This test method can be used to provide information on the strength and quality of core-to-facing bonds. It can also be used to produce flatwise tensile strength data for the core material. While it is primarily used as a quality control test for bonded sandwich panels, it can also be used to produce flatwise tensile strength data for structural design properties, material specifications, and research and development applications.

5.2 Factors that influence the flatwise tensile strength and shall therefore be reported include the following: facing material, core material, adhesive material, methods of material fabrication, facing stacking sequence and overall thickness, core geometry (cell size), core density, adhesive thickness, specimen geometry, specimen preparation, specimen conditioning, environment of testing, specimen alignment, loading procedure, speed of testing, facing void content, adhesive void content, and facing volume percent reinforcement. Properties that may be derived from this test method include flatwise tensile strength.

6. Interferences

6.1 *Material and Specimen Preparation*—Poor material fabrication practices, lack of control of fiber alignment, and damage induced by improper specimen machining are known causes of high data scatter in composites in general. Specific material factors that affect sandwich composites include variability in core density and degree of cure of resin in both facing matrix material and core bonding adhesive. Important aspects of sandwich panel specimen preparation that contribute to data scatter are incomplete or nonuniform core bonding to facings, misalignment of core and facing elements, the existence of joints, voids or other core and facing discontinuities, out-of-plane curvature, facing thickness variation, and surface roughness.

6.2 *System Alignment*—Excessive bending will cause premature failure. Every effort should be made to eliminate excess bending from the test system. Bending may occur as a result of misaligned grips, poor specimen preparation, or poor alignment of the bonding blocks and loading fixture. If there is any doubt as to the alignment inherent in a given test machine, then the alignment should be checked as discussed in Test Method D 3039/D 3039M.

6.3 *Geometry*—Specific geometric factors that affect sandwich flatwise tensile strength include core cell geometry, core thickness, specimen shape (square or circular), adhesive thickness, facing thickness, and facing per-ply thickness.

6.4 *Environment*—Results are affected by the environmental conditions under which the tests are conducted. Specimens tested in various environments can exhibit significant differences in both strength behavior and failure mode. Critical environments must be assessed independently for each facing, adhesive and core material tested.

6.5 *Conditioning*—As it is inappropriate to bond a moisture-conditioned specimen to the bonding blocks, it is necessary to perform the bonding operation prior to such conditioning. The presence of the bonding blocks will affect the degree of moisture intake into the specimen, in comparison to a non-bonded sample.

7. Apparatus

7.1 *Micrometers*—The micrometer(s) shall use a 4- to 5-mm [0.16- to 0.20-in.] nominal diameter ball-interface on irregular surfaces such as the bag-side of a facing laminate, and a flat anvil interface on machined edges or very smooth-tooled surfaces. The accuracy of the instrument(s) shall be suitable for reading to within 1 % of the sample length, width and thickness. For typical specimen geometries, an instrument with an accuracy of ±25 mm [±0.001 in.] is desirable for thickness, length and width measurement.

7.2 *Loading Fixtures*—The loading fixtures shall be self-aligning and shall not apply eccentric loads. A satisfactory type of apparatus is shown in Fig. 1. The loading blocks shall be sufficiently stiff to keep the bonded core or facings essentially flat under load. Loading blocks 40 to 50 mm [1.5 to 2.0 in.] thick have been found to perform satisfactorily. Permissible tolerances for the loading blocks (along with alignment requirements) are provided in Fig. 2.

7.3 *Testing Machine*—The testing machine shall be in accordance with Practices E 4 and shall satisfy the following requirements:

7.3.1 *Testing Machine Configuration*—The testing machine shall have both an essentially stationary head and a movable head.

7.3.2 *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 in accordance with 11.6.

7.3.3 *Load Indicator*—The testing machine load-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

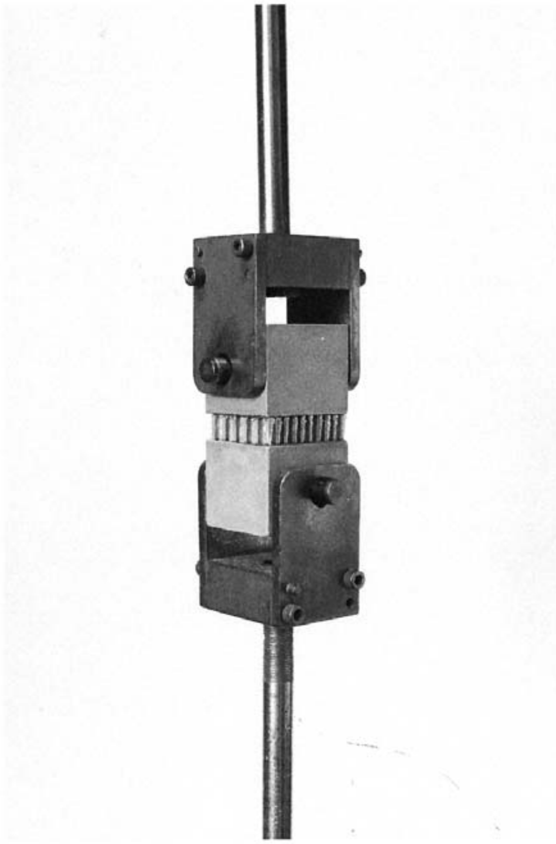

FIG. 1 Flatwise Tension Test Setup

indicate the force with an accuracy over the force range(s) of interest of within ±1 % of the indicated value.

7.4 *Conditioning Chamber*—When conditioning materials at non-laboratory environments, a temperature/vapor-level controlled environmental conditioning chamber is required that shall be capable of maintaining the required temperature to within ±3°C [±5°F] and the required relative humidity level to within ±3 %. Chamber conditions shall be monitored either on an automated continuous basis or on a manual basis at regular intervals.

7.5 *Environmental Test Chamber*—An environmental test chamber is required for test environments other than ambient testing laboratory conditions. This chamber shall be capable of maintaining the gage section of the test specimen at the required test environment during the mechanical test.

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, as in the case of a designed experiment. For statistically significant data, consult the procedures outlined in Practice E 122. Report the method of sampling.

8.2 *Geometry*—Test specimens shall have a square or circular cross-section, and shall be equal in thickness to the sandwich panel thickness. Minimum specimen facing areas for various types of core materials are as follows:

8.2.1 *Continuous Bonding Surfaces (for example, balsa wood, foams)*—The minimum facing area of the specimen shall be 625 mm^2 [1.0 in.^{2}].

8.2.2 *Discontinuous Cellular Bonding Surfaces (for example, honeycomb)*—The required facing area of the specimen is dependent upon the cell size, to ensure a minimum number of cells are tested. Minimum facing areas are recommended in Table 1 for the more common cell sizes. These are intended to provide approximately 60 cells minimum in the test specimen. The largest facing area listed in the table (5625 mm^2 [9.0 in.^{2}]) is a practical maximum for this test method. Cores with cell sizes larger than 9 mm [0.375 in.] may require a smaller number of cells to be tested in the specimen.

8.3 *Specimen Preparation and Machining*—Specimen preparation is extremely important for this test method. Take precautions when cutting specimens from large panels to avoid notches, undercuts, rough or uneven surfaces, or delaminations due to inappropriate machining methods. Obtain final dimensions by water-lubricated precision sawing, milling, or grinding. The use of diamond tooling has been found to be extremely effective for many material systems. Edges should be flat and parallel within the specified tolerances. Record and report the specimen cutting preparation method.

8.4 *Labeling*—Label the test specimens so that they will be distinct from each other and traceable back to the panel of origin, and will neither influence the test nor be affected by it.

8.5 *Loading Fixture Bonding*—The loading blocks shall be bonded to the core or facings of the test specimen using a suitable adhesive. To minimize thermal exposure effects upon the existing core-to-facing bonds, it is recommended that the assembly bonding temperature be at room temperature, or at least 28°C [50°F] lower than that at which the sandwich was originally bonded. Similarly, the assembly bonding pressure shall not be greater than the original facing-to-core bonding pressure. Permissible tolerances for the bonded assembly (along with alignment requirements) are provided in Fig. 2.

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 *Standard Conditioning Procedure*—Unless a different environment is specified as part of the experiment, condition the test specimens in accordance with Procedure C of Test Method D 5229/D 5229M, and store and test at standard laboratory atmosphere (23 ± 3°C [73 ± 5°F] and 50 ± 5 % relative humidity).

11. Procedure

11.1 *Parameters to Be Specified Before Test*:

11.1.1 The specimen sampling method, specimen geometry, and conditioning travelers (if required).

11.1.2 The properties and data reporting format desired.

NOTE 1—Determine specific material property, accuracy, and data reporting requirements prior to test for proper selection of instrumentation and data recording equipment. Estimate the specimen strength to aid in transducer selection, calibration of equipment, and determination of equipment settings.

11.1.3 The environmental conditioning test parameters.

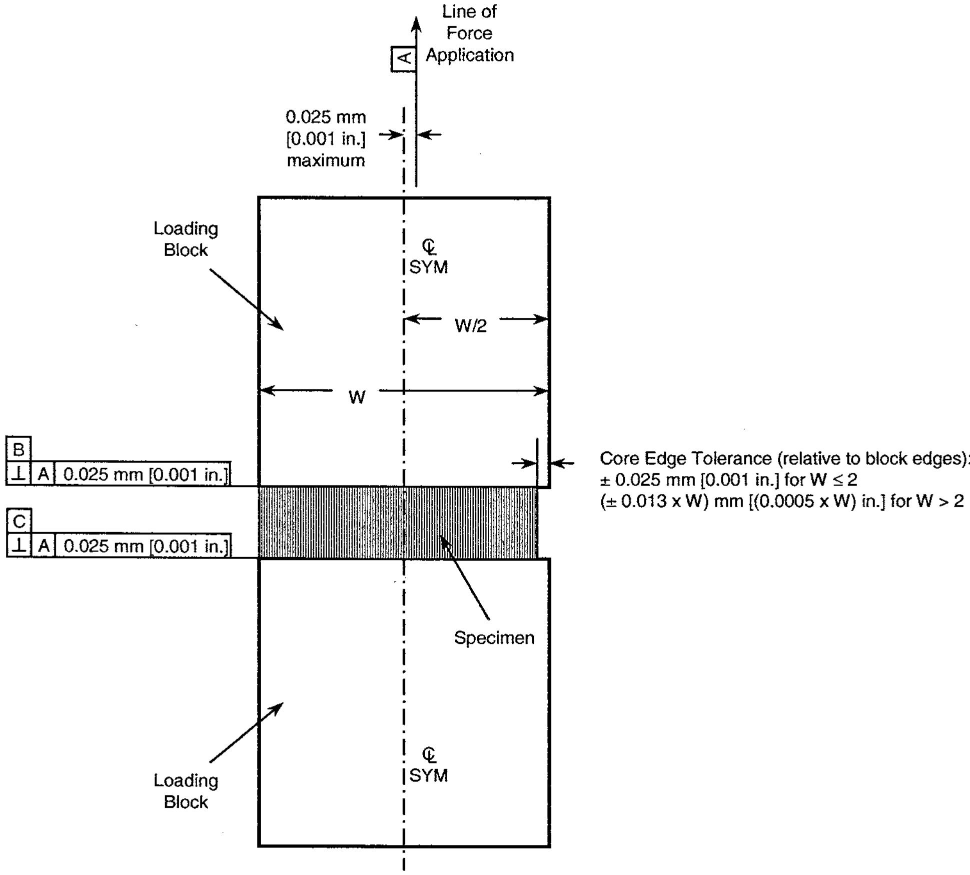

FIG. 2 Permissible Bonded Assembly Tolerances

TABLE 1 Recommended Minimum Specimen Facing Area

Minimum Cell Size (mm [in.])	Maximum Cell Size (mm [in.])	Minimum Facing Area (mm^2 [in.^{2}])
-	3.0 [0.125]	625 [1.0]
3.0 [0.125]	6.0 [0.250]	2500 [4.0]
6.0 [0.250]	9.0 [0.375]	5625 [9.0]

11.1.4 If performed, sampling method, specimen geometry, and test parameters used to determine facing density and reinforcement volume.

11.2 *General Instructions*:

11.2.1 Report any deviations from this test method, whether intentional or inadvertent.

11.2.2 If specific gravity, density, facing reinforcement volume, or facing void volume are to be reported, then obtain these samples from the same panels being tested. Specific gravity and density may be evaluated in accordance with Test Methods D 792. Volume percent of composite facing constituents may be evaluated by one of the matrix digestion procedures of Test Method D 3171, or, for certain reinforcement materials such as glass and ceramics, by the matrix burn-off technique in accordance with Test Method D 2584. The void content equations of Test Method D 2734 are applicable to both Test Method D 2584 and the matrix digestion procedures.

11.2.3 Following final specimen machining, but before conditioning and testing, measure the specimen length and width or diameter. The accuracy of these measurements shall be within 0.5 % of the dimension. Measure the specimen thickness; the accuracy of this measurement shall be within ±25 mm [±0.001 in.]. Record the dimensions to three significant figures in units of millimetres [inches].

11.3 Bond the specimen to the bonding blocks, in accordance with the requirements of 8.5.

11.4 Condition the bonded specimens as required. Store the specimens in the conditioned environment until test time, if the test environment is different than the conditioning environment.

11.5 Following final specimen conditioning, but before testing, re-measure the specimen length and width or diameter as in 11.2.3.

11.6 *Speed of Testing*—Set the speed of testing so as to produce failure within 3 to 6 min. If the ultimate strength of the material cannot be reasonably estimated, initial trials should be conducted using standard speeds until the ultimate strength of the material and the compliance of the system are known, and speed of testing can be adjusted. The suggested standard head displacement rate is 0.50 mm/min [0.020 in./min].

11.7 *Test Environment*—If possible, test the specimen under the same fluid exposure level used for conditioning. However, cases such as elevated temperature testing of a moist specimen place unrealistic requirements on the capabilities of common testing machine environmental chambers. In such cases, the mechanical test environment may need to be modified, for example, by testing at elevated temperature with no fluid exposure control, but with a specified limit on time to failure from withdrawal from the conditioning chamber. Record any modifications to the test environment.

11.8 *Specimen Installation*—Install the specimen/bonding block assembly into the test machine test fixture.

11.9 *Loading*—Apply a tensile force to the specimen at the specified rate while recording data. Load the specimen until rupture.

11.10 *Data Recording*—Record force versus head displacement continuously, or at frequent regular intervals. Record the maximum force, the failure force, and the head displacement at, or as near as possible to, the moment of rupture.

11.11 *Failure Modes*—Adhesive failures that occur at the bond to the loading blocks are not acceptable failure modes and the data shall be noted as invalid. The following failure modes are considered to be acceptable:

11.11.1 *Core Failure*—Tensile failure of the sandwich core. Pieces of the core may remain in the adhesive that bonds the core to the block or facing.

11.11.2 *Cohesive Failure of Core-Facing Adhesive*—Failure in the adhesive layer used to bond the facing to the core, with adhesive generally remaining on both the facing and core surfaces.

11.11.3 *Adhesive Failure of Core-Facing Adhesive*—Failure in the adhesive layer used to bond the facing to the core, with adhesive generally remaining on either the facing or the core surface, but not both.

11.11.4 *Facing Tensile Failure*—Tensile failure of the facing, usually by delamination of the composite plies in the case of a fiber-reinforced composite facing.

12. Validation

12.1 Values for ultimate properties shall not be calculated for any specimen that breaks at some obvious flaw, unless such flaw constitutes a variable being studied. Retests shall be performed for any specimen on which values are not calculated.

12.2 A significant fraction of failures in a sample population occurring at the bond(s) to the loading blocks shall be cause to reexamine the means of force introduction into the material. Factors considered should include the fixture alignment, adhesive material, specimen surface characteristics, and uneven machining of specimen ends.

13. Calculation

13.1 *Ultimate Strength*—Calculate the ultimate flatwise tensile strength using Eq 1 and report the results to three significant figures.

$$F_z^{ftu} = P_{max} / A \tag{1}$$

where:

F_z^{ftu} = ultimate flatwise tensile strength, MPa [psi],
P_{max} = ultimate force prior to failure, N [lbf], and
A = cross-sectional area, mm^2 [in.^{2}].

13.2 *Statistics*—For each series of tests calculate the average value, standard deviation, and coefficient of variation (in percent) for ultimate flatwise tensile strength:

$$\bar{x} = (\sum_{i=1}^{n} x_1) \tag{2}$$

$$S_{n-1} = \sqrt{(\sum_{i=1}^{n} x_1^2 - n\,\bar{x}^2) / (n-1)} \tag{3}$$

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

where:

$\bar{x}$ = sample mean (average),
S_{n-1} = sample standard deviation,
CV = sample coefficient of variation, %,
n = number of specimens, and
x_1 = measured or derived property.

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 panel fabrication parameters, shall be the responsibility of the requestor):

NOTE 2—Guides E 1309, E 1434 and E 1471 contain data reporting recommendations for composite materials and composite materials mechanical testing.

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

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

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

14.1.4 Identification of all the materials consistuent to the sandwich panel specimen tested, including for each: material specification, material type, manufacturer's material designation, manufacturer's batch or lot number, source (if not from manufacturer), date of certification, expiration of certification, facing filament diameter, tow or yarn filament count and twist, sizing, form or weave, fiber areal weight, matrix type, facing matrix content and volatiles content, ply orientation and stacking sequence of the facings.

14.1.5 Description of the fabrication steps used to prepare the sandwich panel including: fabrication start date, fabrication end date, process specification, cure cycle, consolidation method, and a description of the equipment used.

14.1.6 Ply orientation and stacking sequence of the facing laminate.

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

14.1.8 Results of any nondestructive evaluation tests.

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

14.1.10 Calibration dates and methods for all measurements and test equipment.

14.1.11 Details of loading blocks and apparatus, including dimensions and material used.

14.1.12 Type of test machine, alignment results, and data acquisition sampling rate and equipment type.

14.1.13 Measured length and width (or diameter) and thickness for each specimen (prior to and after conditioning, if appropriate).

14.1.14 Weight of specimen.

14.1.15 Method of bonding specimens to blocks; adhesive, cure cycle, and pressure.

14.1.16 Conditioning parameters and results.

14.1.17 Relative humidity and temperature of the testing laboratory.

14.1.18 Environment of the test machine environmental chamber (if used) and soak time at environment.

14.1.19 Number of specimens tested.

14.1.20 Speed of testing.

14.1.21 Individual ultimate flatwise tensile strengths and average value, standard deviation, and coefficient of variation (in percent) for the population.

14.1.22 Force versus crosshead displacement data for each specimen so evaluated.

14.1.23 Failure mode, location of failure, percentage of failure area of core, adhesive (cohesive or adhesive failure), or facing 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 method.

15.2 *Bias*—Bias cannot be determined for this method as no acceptable reference standards exist.

16. Keywords

16.1 core; facing; flatwise tension; sandwich; sandwich construction; tensile strength