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Standard Test Method for Edgewise Compressive Strength of Sandwich Constructions[1]

This standard is issued under the fixed designation C364/C364M; 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 covers the compressive properties of structural sandwich construction in a direction parallel to the sandwich facing plane. 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:*

D792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
D883 Terminology Relating to Plastics
D2584 Test Method for Ignition Loss of Cured Reinforced Resins
D2734 Test Methods for Void Content of Reinforced Plastics
D3039/D3039M Test Method for Tensile Properties of Polymer Matrix Composite Materials
D3171 Test Methods for Constituent Content of 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
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
E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods
E456 Terminology Relating to Quality and Statistics
E1012 Practice for Verification of Testing Frame and Specimen Alignment Under Tensile and Compressive Axial Force Application

3. Terminology

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

3.2 *Symbols:* b = width of specimen

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

L = length of specimen

P = force on specimen

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

t_c = core thickness

t_{fs} = nominal facesheet thickness

x_i = 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

σ = facesheet compressive stress

[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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4. Summary of Test Method

4.1 This test method consists of subjecting a sandwich panel to monotonically increasing compressive force parallel to the plane of its faces. The force is transmitted to the panel through either clamped or bonded end supports. Stress and strength are reported in terms of the nominal cross-sectional area of the two facesheets, rather than total sandwich panel thickness, although alternate stress calculations may be optionally specified.

4.2 The only acceptable failure modes for edgewise compressive strength of sandwich constructions are those occurring away from the supported ends. The sandwich column, no matter how short, usually is subjected to a buckling type of failure unless the facings are so thick that they themselves are in the short column class. The failure of the facings manifests itself by wrinkling of the facing, in which the core deforms to the wavy shape of the facings; by dimpling of the facings into the honeycomb cells; by bending of the sandwich, resulting in crimping near the ends as a result of shear failure of the core; or by failure in the facing-to-core bond and associated facesheet buckling.

5. Significance and Use

5.1 The edgewise compressive strength of short sandwich construction specimens provides a basis for judging the load-carrying capacity of the construction in terms of developed facing stress.

5.2 This test method provides a standard method of obtaining sandwich edgewise compressive strengths for panel design properties, material specifications, research and development applications, and quality assurance.

5.3 The reporting section requires items that tend to influence edgewise compressive strength to be reported; these include materials, fabrication method, facesheet lay-up orientation (if composite), core orientation, results of any nondestructive inspections, specimen preparation, test equipment details, specimen dimensions and associated measurement accuracy, environmental conditions, speed of testing, failure mode, and failure location.

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*—Unintended loading eccentricities will cause premature failure. Every effort should be made to eliminate undesirable eccentricities from the test system. Such eccentricities may occur as a result of misaligned grips, poor specimen preparation, or poor alignment of the 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 D3039/D3039M.

6.3 *Geometry*—Specific geometric factors that affect edgewise compressive strength of sandwich panels include facesheet fiber waviness, core cell geometry (shape, density, orientation), core thickness, specimen shape (L/W ratio), and adhesive 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 static strength and failure mode. Critical environments must be assessed independently for each sandwich construction tested.

7. Apparatus

7.1 *Micrometers*—The micrometer(s) shall use a 4- to 6-mm [0.16- to 0.25-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 µm [±0.001 in.] is desirable for thickness, length and width measurement. .

7.2 *Test Fixtures:*

7.2.1 *Spherical Bearing Block,* preferably of the suspended, self-aligning type.

7.2.2 *Lateral End Supports*—Via (*1*) clamps made of rectangular steel bars fastened together so as to clamp the specimen lightly between them (the cross-sectional dimensions of each of these bars shall be not less than 6 mm [0.25 in.], such as that shown in Fig. 1; (*2*) fitting the specimen snugly into a lengthwise slot in a round steel bar, where such bars shall have a diameter not less than the thickness of the sandwich plus 6 mm [0.25 in.], and are suitably retained on the spherical bearing block surfaces; or (*3*) casting the ends of the specimens in resin or other suitable molding material. The cast ends of the specimen should be ground flat and parallel, meeting or exceeding the specimen end tolerances shown in Fig. 2 and Fig. 3.

7.3 *Testing Machine*—The testing machine shall be in accordance with Practices E4 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 *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

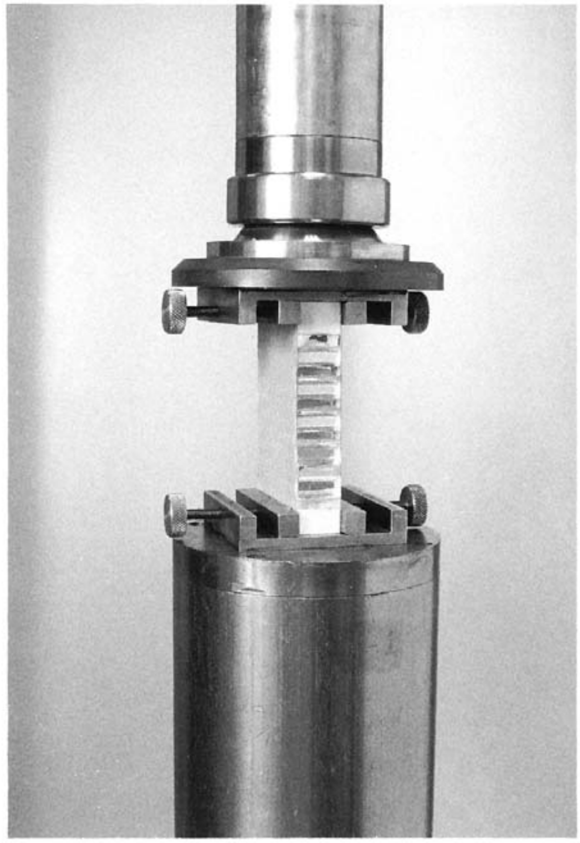


FIG. 1 Edgewise Compression Test Setup

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

7.3.4 *Strain Gage*—Capable of measuring strain to at least 0.0001 mm/mm [0.0001 in./in.] and having a gage length not greater than two thirds of the unsupported length of the specimens to be tested, nor less than three unit cells if the facesheet is a composite fabric material form.

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 entire 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 E122. Report the method of sampling.

8.2 *Geometry*—The test specimens shall be as shown in Fig. 2 (inch-pound units) and Fig. 3 [SI units].

8.3 *Specimen Preparation and Machining*—Guide D5687/D5687M provides recommended specimen preparation practices and should be followed where practical. Of particular note in this end-loaded compression test is the machining quality and dimensional accuracy of the loaded ends, and the overall flatness and parallelism of the sandwich panel, as denoted in Fig. 2 and Fig. 3.

8.3.1 *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.

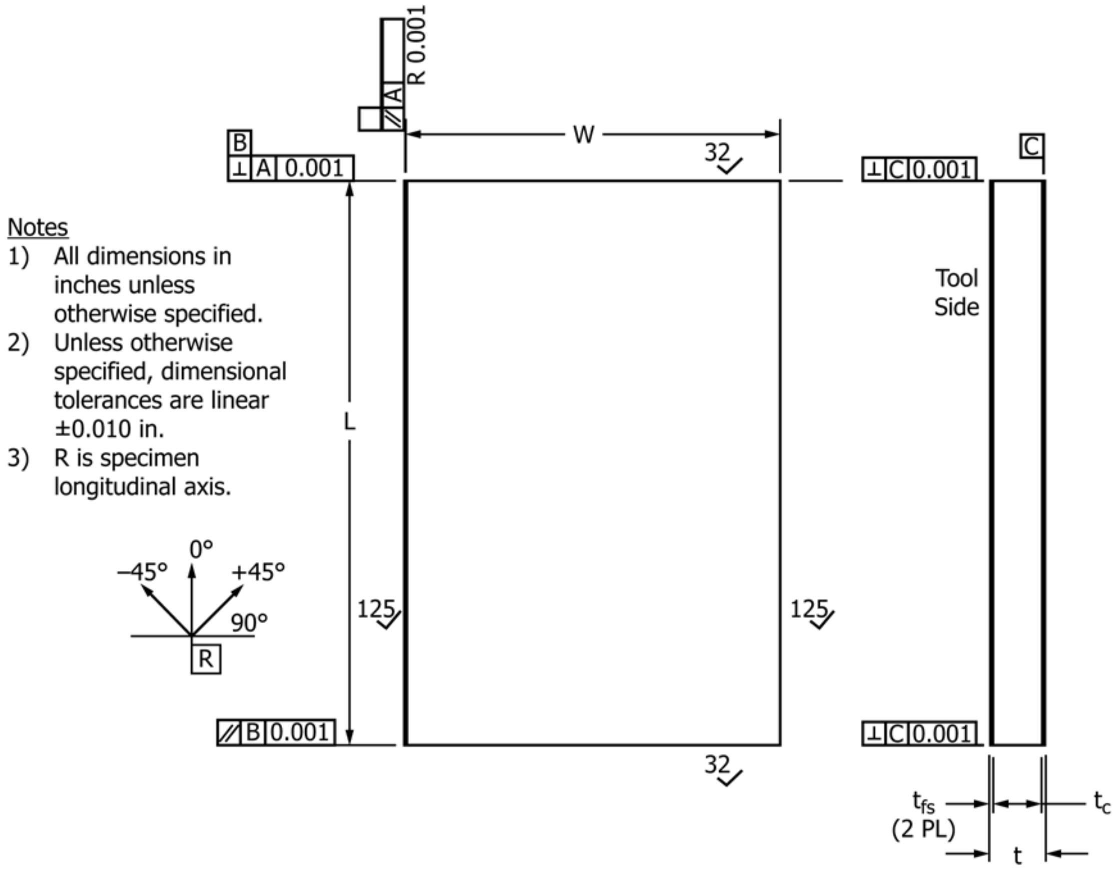
9. Calibration

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 specimen condition is effective moisture equilibrium at a specific relative humidity as established by Test Method D5229/D5229M; however, it the test requester does not specify a pre-test conditioning environment, conditioning is not required and the test specimens may be tested as prepared.

NOTE 1—The term *moisture*, as used in Test Method D5229/D5229M, includes not only the vapor of a liquid and its condensate, but the liquid itself in large quantities, as for immersion.



Dimension	Recommended Range
Length, L (in.)	L ≤ 8 × *t*
Width, W (in.)	2.00 ≤ W ≤ L; W ≥ 2 × *t*; W ≥ 4 × cell widths (honeycomb only)
t, total panel thickness (in.)	As required, in order to be representative of intended use
Facesheet thickness, t_{fs}(in.)	As required, in order to be representative of intended use
Core thickness, t_c(in.)	As required, in order to be representative of intended use

FIG. 2 Test Specimen Dimension (inch-pound version)

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

10.3 If there is no explicit conditioning process, the conditioning process shall be reported as "unconditioned" and the moisture content as "unknown."

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 2—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 parameters.

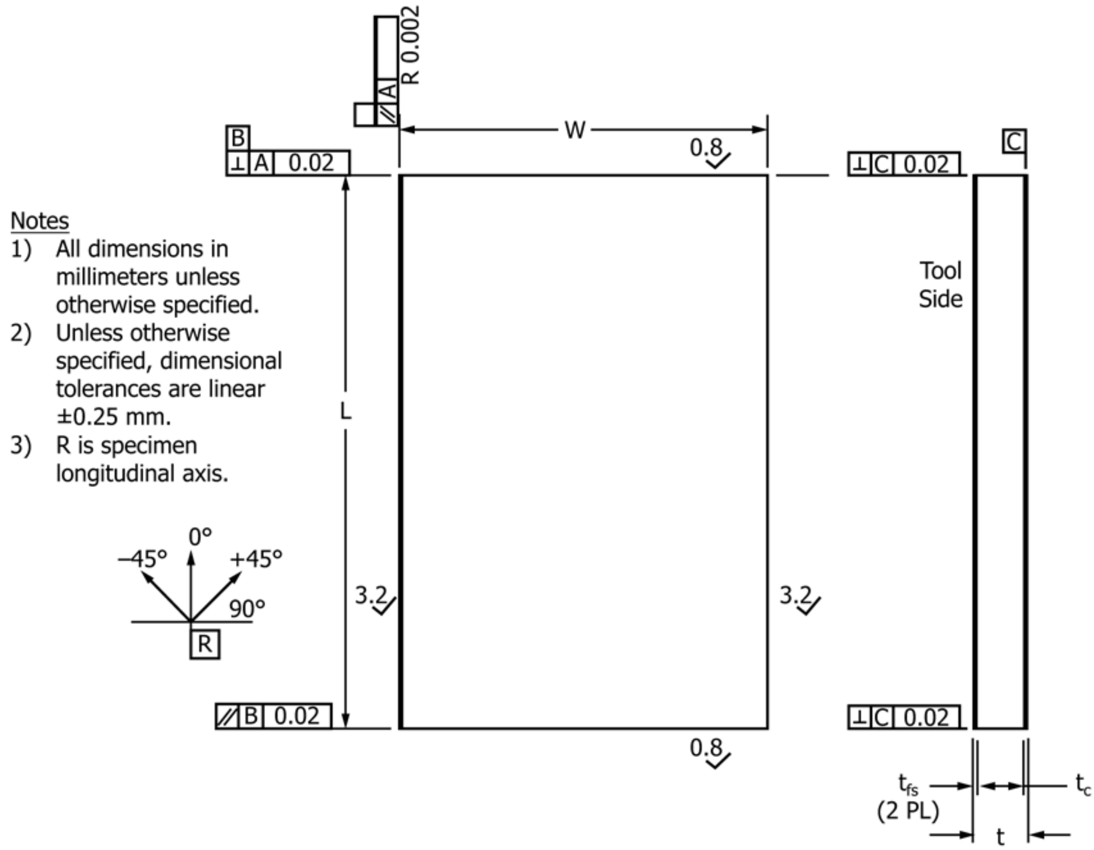
11.1.4 If performed, sampling method, specimen geometry, and test parameters used to determine facing density and reinforcement volume.

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 D792. Volume percent of composite facing constituents may be evaluated by one of the matrix digestion procedures of Test Method D3171, or, for certain reinforcement materials such as glass and ceramics, by the matrix burn-off technique in accordance with Test Method D2584. The void content equations of Test Method D2734 are applicable to both Test Method D2584 and the matrix digestion procedures.

11.2.3 Following final specimen machining, but before conditioning and testing, measure the specimen length and width. The accuracy of these measurements shall be within 1 % of the dimension. Measure the overall specimen thickness; the accuracy of this measurement shall be within ±25 µm [±0.001 in.]. Record the dimensions to three significant figures in units of millimeters [inches].



Dimension	Recommended Range
Length, L (mm)	L ≤ 8 × t
Width, W (mm)	50 ≤ W ≤ L; W ≥ 2 × t; W ≥ 4 × cell widths (honeycomb only)
t, total panel thickness (mm)	As required, in order to be representative of intended use
Facesheet thickness, t_{fs}(mm)	As required, in order to be representative of intended use
Core thickness, t_c(mm)	As required, in order to be representative of intended use

FIG. 3 Test Specimen Dimensions (SI version)

11.3 Bond the specimen in the end-fixtures if such fixtures are used, in accordance with the requirements of 7.2.2, 8.2 and 8.3.

11.4 Condition the 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 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 compressive force to the specimen at the specified rate. Load the specimen until rupture.

11.10 *Data Recording*—Record force versus head displacement, and force versus axial strain (if strain gages are used), continuously, or at frequent regular intervals; for this test method, a sampling rate of 5 to 10 data recordings per second, and a target minimum of 300 data points per test are recommended. If a compliance change or initial damage event are noted, record the force, displacement, strain (if available), and damage mode at such points. Record the maximum force, the failure force, and the head displacement at, or as near as possible to, the moment of rupture.

11.11 *Alignment*—Prior to testing an unfamiliar specimen configuration, or upon experiencing either end-failures or unusual bending failures, it is recommended that a strain-gaged specimen be used to determine the amount of bending inherent in the test configuration. In order to obtain uniform inter- and intra-lab results, follow the following alignment procedure:

11.11.1 A minimum of two axial strain gages, centrally located on opposite faces of the test specimen, is required. If more complete shear and bending information is desired, four-to twelve-gage configurations per Practice E1012 may be used.

11.11.2 Zero the strain gage readings prior to specimen installation in the test fixture and, if a bolted test fixture is used, torque the fixture screws to their nominal torque and record the strain gage readings.

11.11.3 Apply compressive force to the specimen at the specified rate while recording data, until approximately 10% of the anticipated ultimate force is achieved. Reduce the compressive force to 150 N [35 lbf] at an equivalent unloading rate and check strain gage output for proper alignment per the following step.

11.11.4 Review the recorded strain gage data for evidence of specimen bending. A difference in the stress-strain or force-strain slope from opposite faces of the specimen indicates bending in the specimen. Determine percent bending at the maximum applied force for each of the back-to-back gage locations using Eq 1 (or following Practice E1012 for three or more strain gage locations):

$$B_y = Percent\ Bending = \frac{\varepsilon_1 - \varepsilon_2}{\varepsilon_1 + \varepsilon_2} \cdot 100 \quad (1)$$

where:

ε_1 = indicated strain from gage on one face, and
ε_2 = indicated strain from gage on opposite face.

The sign of the calculated Percent Bending indicates the direction in which the bending is occurring. This information is useful in determining if the bending is being introduced by a systematic error in the test specimen, testing apparatus, or test procedure, rather than by random effects from test to test.

11.11.5 Rapid divergence of the strain readings on the opposite faces of the specimen, or rapid increase in percent bending, is indicative of the onset of panel instability. If either of these conditions is found to exist in the strain gage data, or if percent bending at the maximum applied force exceeds 10%, examine the fixture, specimen and load platens for conditions which may promote specimen bending, such as the presence of gaps, loose fixture components, or platen misalignment. Readjust the test set-up as necessary to minimize bending of the specimen at the specified low magnitude of compressive force. Repeat 11.11.2 through 11.11.3 to ensure that the specimen does not buckle or undergo excessive bending prior to final loading.

11.12 *Failure Modes*—Record the mode and location of failure for each specimen. Three-place failure mode descriptors, summarized in Table 1, shall be used. This notation uses the first character to describe the failure type, the second character the failure area, and the third character the failure location. Fig. 4 illustrates commonly observed failure modes. End failures that occur at the bond to the loading blocks or within one specimen-thickness of the end-clamps are not acceptable failure modes and the data shall be noted as invalid. The following failure modes are considered to be acceptable:

TABLE 1 Three-Place Failure Mode Codes

First Character		Second Character		Third Character	
Failure Type	Code	Failure Area	Code	Failure Location	Code
Facesheet Compression	F	At End	A	Top	T
Facesheet Delamination Buckling	B	Gage (>1xt from end)	G	Middle	M
Honeycomb Facesheet Dimpling	D	Various	V	Bottom	B
Core Compression	C	Unknown	U	Various	V
Core Shear	S			Unknown	U
Overall Panel Buckling	P				
Explosive	X				
Other	O				

11.12.1 *Facesheet Buckling*—One or both facesheets exhibit a buckling type of failure, often initiated by facesheet-to-core debonding.

11.12.2 *Facesheet Compression*—Short-column compression failure of one or both facesheets prior to any core or bondline failure, often followed by global buckling of sandwich panel.

11.12.3 *Facesheet Dimpling*—In honeycomb panels, intracell dimpling of the facesheet(s).

11.12.4 *Core Compressive Failure*—Out-of-plane facesheet deformation initiates local core crushing, often followed by global buckling of sandwich panel.

11.12.5 *Core Shear Failure*—Out-of-plane facesheet deformation initiates local core shear failure, often followed by global buckling of sandwich panel.

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 ends shall be cause to reexamine the means of force introduction into the material. Factors considered should include the fixture alignment, potting compound, specimen surface characteristics, and uneven machining of specimen ends.

13. Calculation

13.1 *Ultimate Strength*—Calculate the ultimate edgewise compressive strength using Eq 2 and report the results to three significant figures:

$$\sigma = P_{max}/[w(2\,t_{fs})] \quad (2)$$

where:

σ = ultimate edgewise compressive strength, MPa [psi],
P_{max} = ultimate force prior to failure, N [lbf],
w = width of specimen, mm [in.], and.
t_{fs} = thickness of a single facesheet, mm [in.].

NOTE 3—Accurate measurement of facing thickness is difficult after bonding or co-curing of the facings and core. The test requestor is responsible for specifying the facing thickness to be used for the

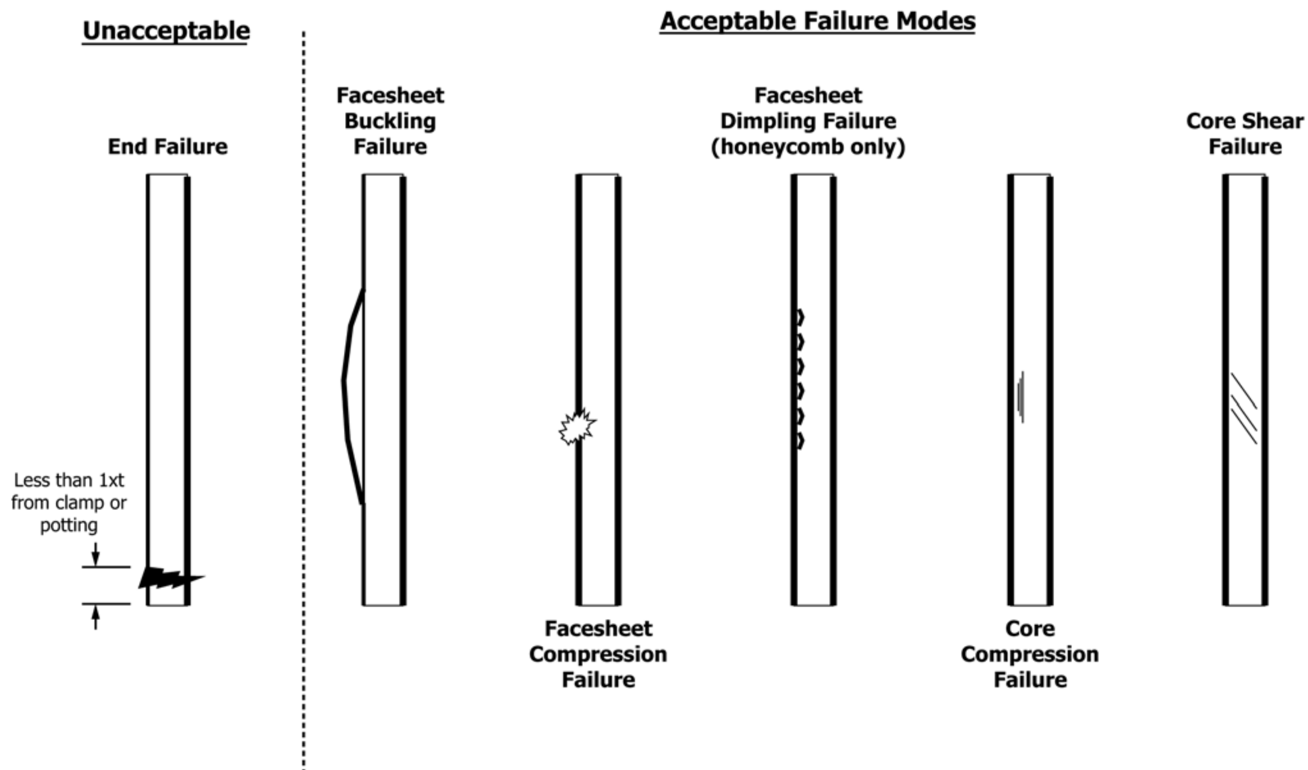


FIG. 4 Commonly Observed Failure Modes for Edgewise Compressive Strength

calculations in this test method. For pre-cured composite facings which are secondarily bonded to the core, the facing thickness should be measured prior to bonding. In these cases the test requestor may specify that either or both measured and nominal thicknesses be used in the calculations. For co-cured facings, the thicknesses are generally calculated using nominal per ply thickness values.

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

$$\bar{x} = \left(\sum_{i=1}^{n} x_i\right) / n \tag{3}$$

$$S_{n-1} = \sqrt{\left(\sum_{i=1}^{n} x_i^2 - n(\bar{x})^2\right) / (n-1)} \tag{4}$$

$$CV = 100 \times S_{n-1} / \bar{x} \tag{5}$$

where:

$\bar{x}$ = sample mean (average),
S_{n-1} = sample standard deviation,
CV = sample coefficient of variation, %,
n = number of specimens, and
x_i = 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):

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 constituent 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, and expiration of certification,

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 Nominal facesheet thickness, and if composite, ply orientation, stacking sequence, density, filament diameter, tow or yarn filament count and twist, sizing, form or weave, fiber areal weight, matrix type, facing matrix content, volume percent reinforcement, and void content,

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 Sandwich core and adhesive properties, such as nominal thickness, density, and (if honeycomb) cell size, and ribbon direction,

14.1.9 Results of any nondestructive evaluation tests,

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

14.1.11 Calibration dates and methods for all measurements and test equipment, 14.1.12 Details of loading blocks and apparatus, including dimensions and material used,

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

14.1.14 Measured length, width, and overall thickness for each specimen (prior to and after conditioning, if appropriate),

14.1.15 Method of potting ends of specimens, if any; 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 edgewise compressive strengths and average value, standard deviation, and coefficient of variation (in percent) for the population,

14.1.22 Force versus crosshead displacement data, and force versus strain data (for each specimen so instrumented),

14.1.23 Failure mode and location of failure 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.

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

16. Keywords

16.1 edgewise; facing compressive stress; sandwich; sandwich construction