Designation: D7336/D7336M – 16

Standard Test Method for Static Energy Absorption Properties of Honeycomb Sandwich Core Materials[1]

This standard is issued under the fixed designation D7336/D7336M; 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 determines the static energy absorption properties (compressive crush stress and crush stroke) of honeycomb sandwich core materials. These properties are usually determined for design purposes in a direction normal to the plane of facings as the honeycomb core material would be placed in a structural sandwich construction.

1.2 Permissible core materials are limited to those in honeycomb form.

1.3 This test method is not intended for use in crush testing of stabilized honeycomb core materials (for which the facing plane surfaces of the honeycomb core material are dipped in resin to resist local crushing) or sandwich specimens (for which facings are bonded to the honeycomb core material).

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 system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C271/C271M Test Method for Density of Sandwich Core Materials
D883 Terminology Relating to Plastics
D3878 Terminology for Composite Materials
D5229/D5229M Test Method for Moisture Absorption Properties and Equilibrium Conditioning of Polymer Matrix Composite Materials
E4 Practices for Force Verification of Testing Machines
E6 Terminology Relating to Methods of Mechanical Testing
E18 Test Methods for Rockwell Hardness of Metallic Materials
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, as well as terms relating to sandwich constructions. Terminology D883 defines terms relating to plastics. Terminology E6 defines terms relating to mechanical testing. Terminology 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.

NOTE 1—If the term represents a physical quantity, its analytical dimensions are stated immediately following the term (or letter symbol) in fundamental dimension form, using the following ASTM standard symbology for fundamental dimensions, shown within square brackets: [*M*] for mass, [*L*] for length, [*T*] for time, [θ] for thermodynamic temperature, and [*nd*] for non-dimensional quantities. Use of these symbols is restricted to analytical dimensions when used with square brackets, as the symbols may have other definitions when used without the brackets.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *cell size [L], n—in a honeycomb core*, the distance between two parallel and opposite cell walls at node bond areas, measured transverse to the ribbon direction.

3.2.2 *node bond area, n—in a honeycomb core*, the area between two cells at which the component walls of the cells are bonded or attached.

3.3 *Symbols:*

[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.

Current edition approved April 1, 2016. Published April 2016. Originally approved in 2007. Last previous edition approved in 2012 as D7336/D7336M – 12. DOI: 10.1520/D7336_D7336M-16.

[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.

A = cross-sectional area of a test specimen prior to compressive crush testing
CV = coefficient of variation statistic of a sample population for a given property (in percent)
K_A = initial chord slope of the force versus displacement/deformation curve
K_B = post-crush slope of the force versus displacement/deformation curve
P_{cr} = average force carried by test specimen during compressive crushing
s_{cr} = crush stroke in percent
$S_{n\text{-}1}$ = standard deviation statistic of a sample population for a given property
t_i = thickness of a test specimen prior to compressive crush testing
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
δ = recorded displacement/deflection
δ_A = displacement/deflection at which the initial chord slope intersects the displacement/deformation axis
δ_B = displacement/deflection at which the post-crushing slope equals the initial chord slope
δ_{cr} = crush stroke
Δ = normalized displacement/deflection
σ_{cr} = average compressive crush stress

4. Summary of Test Method

4.1 This test method consists of subjecting a sandwich honeycomb core material to a uniaxial compressive force normal to the plane of the facings as the honeycomb core material would be placed in a structural sandwich construction. The force is transmitted to the sandwich honeycomb core material using loading platens attached to the testing machine. Compressive force is applied past the initial failure force, such that the honeycomb core material is crushed under continuous displacement of the loading platens. Force versus loading platen displacement data are recorded and used to determine the crush stress and crush stroke.

5. Significance and Use

5.1 Sandwich honeycomb core materials are used extensively in energy absorption applications, due to their ability to sustain compressive loading while being crushed. Proper design of energy absorption devices utilizing sandwich honeycomb core materials requires knowledge of the compressive crush stress and crush stroke properties of the honeycomb core material.

5.2 The procedures contained within this standard are intended to assess the crush stress and crush stroke properties of the sandwich honeycomb core material under static compressive loading. The dynamic crush stress of the honeycomb core material may vary from that measured under static loading, depending upon factors such as honeycomb core material thickness, core material density, impact velocity, etc.

5.3 This test method provides a standard method of obtaining the compressive crush stress and crush stroke for sandwich honeycomb core material structural design properties, material specifications, research and development applications, and quality assurance.

5.4 This test method is not intended for use in crush testing of stabilized honeycomb core materials (for which the facing plane surfaces of the honeycomb core material are dipped in resin to resist local crushing) or sandwich specimens (for which facings are bonded to the honeycomb core material).

5.5 Factors that influence the compressive crush stress and crush stroke and shall therefore be reported include the following: honeycomb core material, methods of material fabrication, core material geometry (nominal cell size), core material density, specimen geometry, specimen preparation, specimen conditioning, environment of testing, specimen alignment, pre-crush procedure, pre-crush depth, loading procedure, and speed of testing.

6. Interferences

6.1 *Material and Specimen Preparation*—Poor material fabrication practices and damage induced by improper specimen machining are known causes of high data scatter in composites and sandwich structures in general. Important aspects of sandwich core material specimen preparation that contribute to data scatter include the existence of joints, voids or other core material discontinuities, out-of-plane curvature/warpage, and surface roughness.

6.2 *System Alignment*—Non-uniform loading over the surface of the test specimen may cause premature or uneven crushing. This may occur as a result from non-uniform thickness, failing to locate the specimen concentrically in the fixture, or system or fixture misalignment.

6.3 *Geometry*—Specific geometric factors that affect compressive crush stress and crush stroke include honeycomb core material cell geometry, core material thickness, and specimen shape (square or circular). Thicker specimens are generally desirable, as the crush stroke is greater for thick specimens compared to thin specimens.

6.4 *Pre-Crushing*—It is recommended to pre-crush honeycomb core material specimens prior to test, as historical crush force versus displacement data for pre-crushed specimens have displayed greater uniformity (consistency of the crush force level for varying crush stroke) than have similar data for non pre-crushed specimens. If tests are performed using analog equipment to record force versus displacement data, pre-crushing may be necessary to ensure the crush force is recorded on a high sensitivity force scale (if not pre-crushed, the peak force to initially fail the specimen may be substantially higher than the crush force). Pre-crushing also aids interpretation of force versus displacement data and calculation of crush stroke values. Results are affected by the pre-crush depth and uniformity of pre-crushing.

6.5 *Environment*—Results are affected by the environmental conditions under which specimens are conditioned, as well as the conditions under which the tests are conducted. Specimens tested in various environments can exhibit significant differences in both crush stress and crush stroke. Critical environments must be assessed independently for each honeycomb core material tested.

7. Apparatus

7.1 *Micrometers and Calipers*—A micrometer having a flat anvil interface, or a caliper of suitable size, shall be used. The accuracy of the instrument(s) shall be suitable for reading to within 1 % of the sample length and width (or diameter) and thickness. For typical specimen geometries, an instrument with an accuracy of ±250 µm [±0.010 in.] is desirable for thickness, length and width (or diameter) measurement.

7.2 *Loading Platens*—Force shall be introduced into the specimen using fixed flat platens (58 HRC minimum as specified in Test Methods E18). One platen may be of the spherical seat (self-aligning) type, if it is capable of being locked in a fixed position once the platen has contacted and aligned with the specimen. The platens shall be well-aligned (centered with respect to the drive mechanism loading train) and shall not apply eccentric forces. A satisfactory type of apparatus is shown in Figs. 1 and 2. The platen surfaces shall extend beyond the test specimen periphery. If the platens are not sufficiently hardened, or simply to protect the platen surfaces, a hardened plate (with parallel surfaces) can be inserted between each end of the specimen and the corresponding platen.

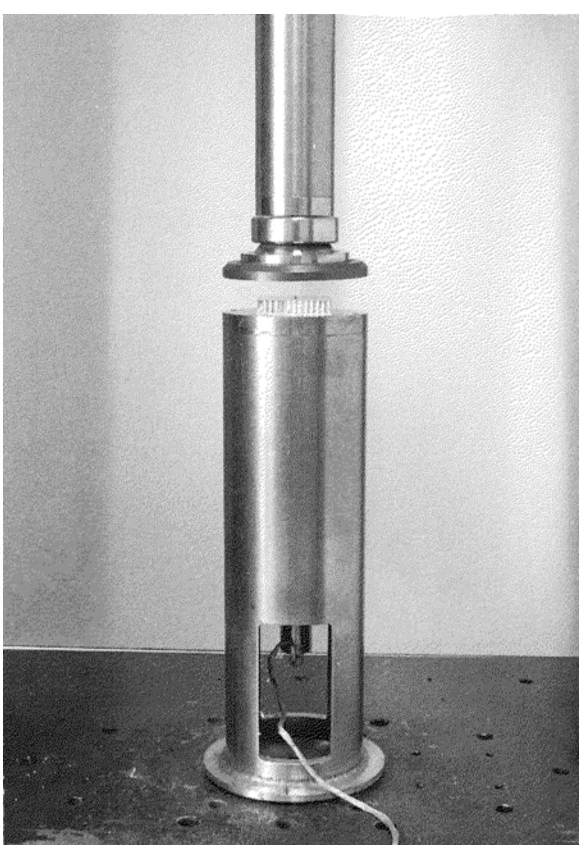

FIG. 1 Platen with Transducer and Rod Setup

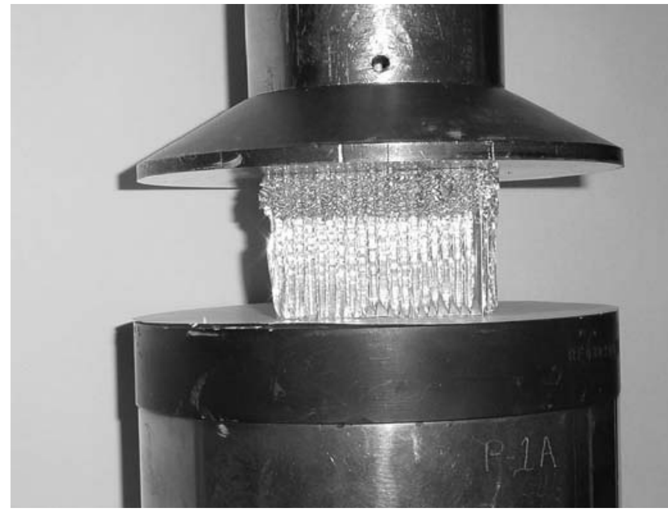

FIG. 2 Close-up of Specimen Between Loading Platens Being Crushed

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

7.3.4 *Crosshead Displacement Indicator*—The testing machine shall be capable of monitoring and recording the crosshead displacement (stroke) with a precision of at least ±1 %. If machine compliance is significant, it is acceptable to measure the displacement of the movable head using a LVDT, compressometer or similar device with ±1 % precision on displacement. A transducer and rod setup, shown in Figs. 1 and 2, has been found to work satisfactorily. In the example shown, a small hole is drilled in the center of the bottom loading platen, and a transducer rod is inserted through the hole and the honeycomb core test specimen, such that it contacts the upper loading platen. If such an apparatus is used, the transducer rod diameter shall be no greater than the cell size, so that the transducer rod can be inserted through the test specimen without distorting the core cell geometry.

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.

7.6 *Pre-Crushing Device*—Crush strength and stroke data for pre-crushed honeycomb core materials typically display greater uniformity than have similar data for non pre-crushed specimens. Serrated plates have been used successfully as pre-crushing devices for honeycomb core materials; acceptable reference serrated plate configurations are shown in Figs. 3 and 4. The pre-crushing device must be capable of providing a relatively uniform pre-crush depth of 1.0 ± 0.5 mm [0.03 ± 0.02 in.].

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*—Test specimens shall have a square or circular cross-section and a minimum thickness of 25 mm [1.0 in.]. 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. Core materials with cell sizes larger than 9 mm [0.375 in.] may require a smaller number of cells to be tested in the specimen.

NOTE 2—The specimen's cross-sectional area is defined in the facing plane, in regard to the orientation that the honeycomb core material would be placed in a structural sandwich construction. For a honeycomb core material, the cross-sectional area is defined in the plane of the cells, which is perpendicular to the orientation of the cell walls.

8.3 *Specimen Preparation and Machining*—Prepare the test specimens so that the reference loading surfaces are parallel to each other and perpendicular to the sides of the specimen. Take precautions when cutting specimens from large sheets of honeycomb core material to avoid notches, undercuts, rough or uneven surfaces due to inappropriate machining methods. Obtain final dimensions by water-lubricated precision sawing, milling, or grinding. The use of diamond tooling has been

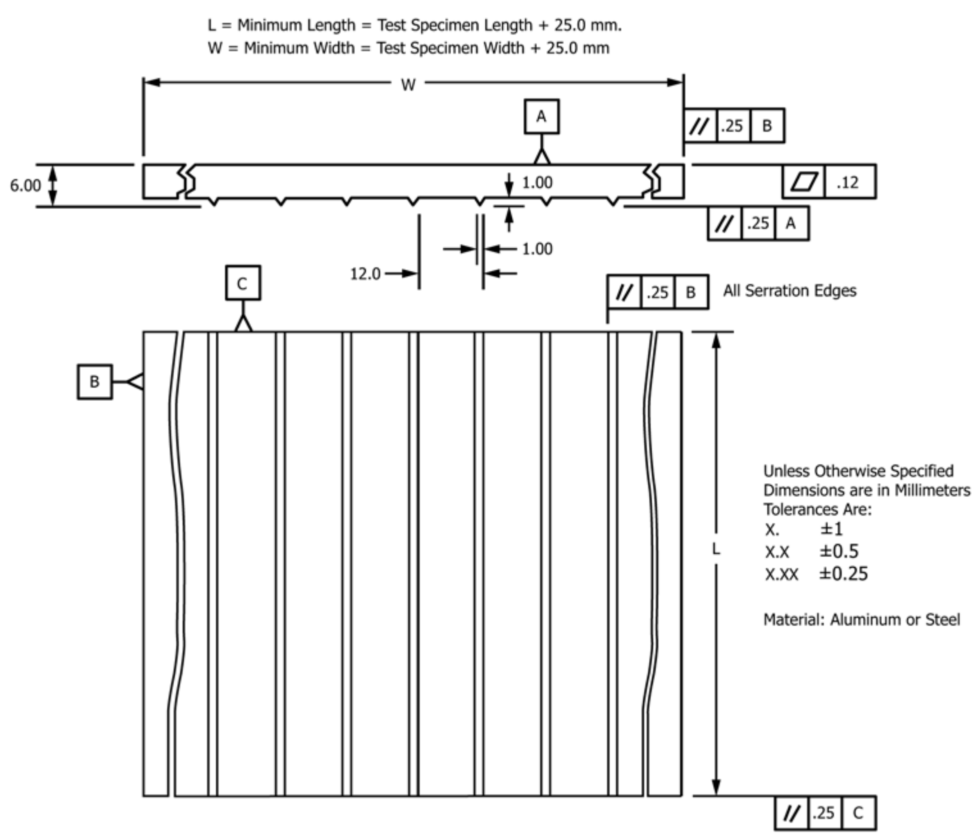

FIG. 3 Representative Serrated Plate for Honeycomb Core Material Pre-Crushing (SI Version)

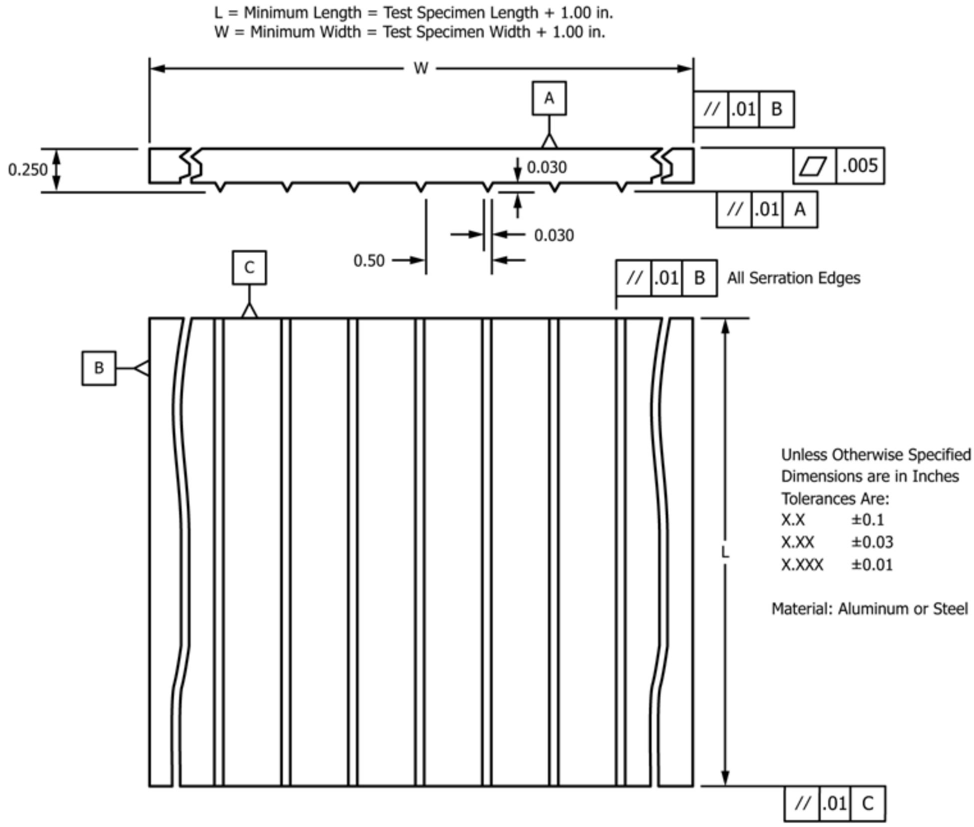

FIG. 4 Representative Serrated Plate for Honeycomb Core Material Pre-Crushing (Inch-Pound Version)

TABLE 1 Recommended Minimum Specimen Cross-Sectional Area

Minimum Cell Size (mm [in.])	Maximum Cell Size (mm [in.])	Minimum Cross-Sectional 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]

found to be extremely effective for many material systems. 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 sheet 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 condition is effective moisture equilibrium at a specific relative humidity as established by Test Method D5229/D5229M; however, if the test requestor does not explicitly specify a pre-test conditioning environment, no conditioning is required and the test specimens may be tested as prepared.

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

NOTE 3—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.

10.3 If no explicit conditioning process is performed the specimen 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 4—Determine specific material property, accuracy, and data reporting requirements prior to test for proper selection of instrumentation and data recording equipment. Estimate the specimen crush stress to aid in transducer selection, calibration of equipment, and determination of equipment settings.

11.1.3 The environmental conditioning test parameters.

11.1.4 The method of pre-crushing and target pre-crush depth, if performed.

11.2 *General Instructions:*

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

11.2.2 If honeycomb core material density is to be reported, then obtain these samples from the same sheet of honeycomb core material being tested. Density may be evaluated in accordance with Test Method C271/C271M.

11.2.3 Following final specimen machining, but before conditioning and testing, measure the specimen length and width (or diameter) and thickness. Measure the specimen thickness, length and width (or diameter) with an accuracy of ±250 µm [±0.010 in.], ensuring the accuracy of the measurements is within 1.0 % of the dimension. Record the dimensions to three significant figures in units of millimeters [inches].

11.3 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.

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

11.5 *Pre-Crushing*—Pre-crushed specimen crush stress data for honeycomb core materials typically display greater uniformity than have similar data for non pre-crushed specimens. If a honeycomb core material specimen is to be pre-crushed, pre-fail the upper surface of the specimen by pressing the serrated plate prepared in 7.6 into the core material surface. Press the plate into the core material multiple times, in multiple directions, until the surface of the core is uniformly pre-crushed. The pre-crush depth shall be 1.0 ± 0.5 mm [0.03 ± 0.02 in.]. After pre-crushing, the surfaces of the honeycomb core material specimen shall be parallel and perpendicular within 0.5 mm (0.02 in.).

11.6 *Speed of Testing*—Set the speed of testing so as to completely crush the honeycomb core material within 1 to 3 min. The suggested standard head displacement rate is 25 mm/min [1.0 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*—Mark a rectangle or circle (depending upon the specimen's cross-sectional shape) on the lower platen to help center the specimen between the platens. Place the specimen on the lower platen, accommodating the LVDT or compressometer if utilized.

NOTE 5—Take care to align specimens well between the platens (such that the specimen is centered along the line of the drive mechanism loading train), in order to distribute the applied force as uniformly as possible over the entire loading surface. This will help to ensure that the specimen edges are loaded uniformly. Non-uniform loading often results in failures that are confined to one corner or one edge of the specimen.

11.9 *Pre-Loading*—Move the actuator or crosshead such that the loading platen contacts the LVDT/compressometer (if utilized) and specimen, and apply a standard initial load of 45 N [10 lbf]. Zero and balance the displacement indicator, and lock the spherical seat platen in position if utilized.

11.10 *Loading*—Apply a compressive force to the specimen at the specified rate while recording data. Load the specimen as the core material is crushed (see Fig. 5), and monitor the force versus head displacement or force versus LVDT/compressometer deflection data. For honeycomb core material specimens, a nearly constant force magnitude will be maintained as the core material is compressed and crushed (see Fig. 6). Load the specimen until the applied force begins to increase significantly above the crush force, and attains a magnitude at least 50 % greater than the constant force magnitude initially observed.

11.11 *Data Recording*—Record force versus head displacement or force versus LVDT/compressometer deflection data 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.

11.12 *Failure Modes*—Uniform compressive failure of the sandwich core material is the only acceptable failure mode. Compressive failures confined to one corner or edge of the specimen shall be considered invalid.

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 for which values are not calculated.

12.2 A significant fraction of failures in a sample population occurring along one corner or one edge shall be cause to reexamine the means of force introduction into the specimen. Factors considered should include the loading platen alignment, specimen surface characteristics, and uneven machining of specimen surfaces and edges.

13. Calculation

13.1 *Thickness Designation*—For the following calculations, use of the pre-crush honeycomb core material

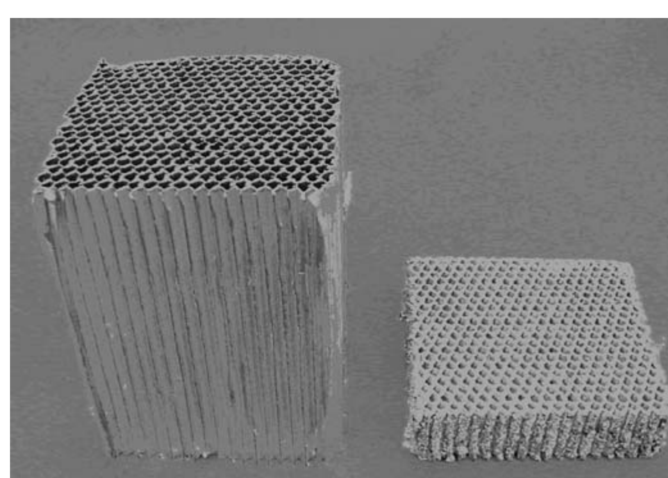

FIG. 5 Honeycomb Core Material Specimens Prior to and After Crush Testing

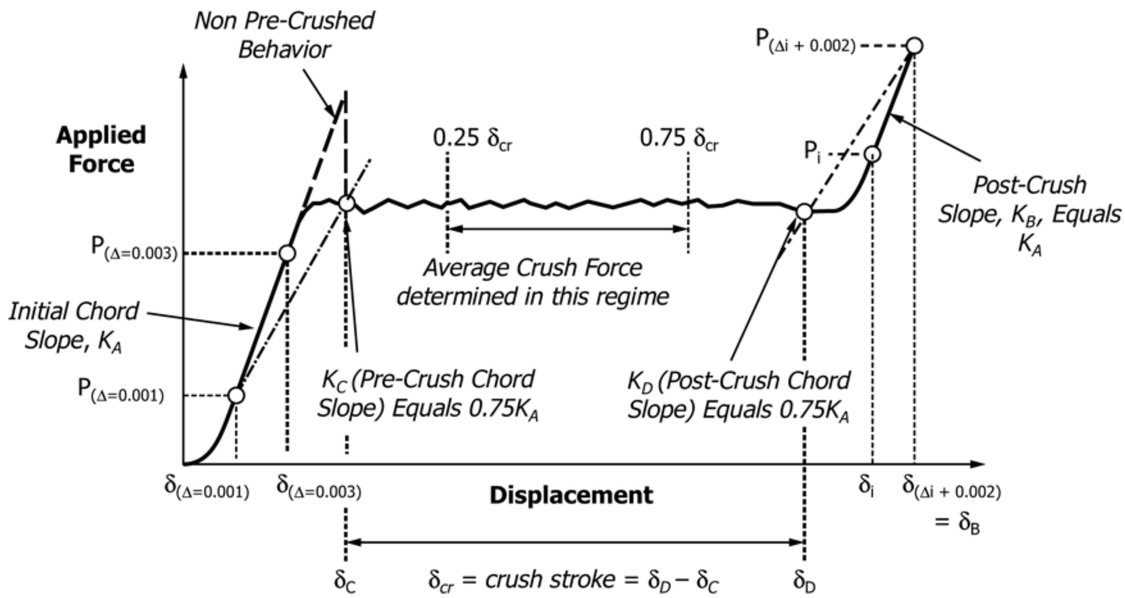

FIG. 6 Definitions Describing Sandwich Core Material Crush Force Versus Displacement/Deflection

thickness, t_i, in the determination of normalized displacements is acceptable, as subsequent calculations are intended to provide a relative assessment of the stiffness, and are not intended to provide rigorous assessments of the core material modulus.

13.2 *Normalized Displacements*—For each recorded displacement value, calculate the corresponding normalized displacement and report the results to three significant figures.

$$\Delta = \frac{\delta}{t_i} \quad (1)$$

where:

Δ = normalized displacement, mm/mm [in./in.];
δ = recorded displacement, mm [in.]; and
t_i = measured thickness of honeycomb core material specimen prior to loading and pre-crushing, mm [in.].

13.3 *Initial Chord Slope*—Calculate the initial chord slope of the force versus displacement curve using Eq 2 and report the results to three significant figures. Chord slopes are to be determined between two specific force-displacement points of the force versus displacement curve. The displacement values selected are intended to represent the lower half of the core material's force versus displacement curve. For honeycomb core materials which fail below Δ = 0.006, a deflection range of 25 to 50 % of ultimate is recommended. However, for some other materials, another range may be more appropriate; an alternative range may be necessary if the force versus displacement behavior is nonlinear prior to the onset of crushing.

$$K_A = \frac{\left(\left(P_{(\Delta=0.003)} - P_{(\Delta=0.001)}\right)\right)}{\left(\left(\delta_{(\Delta=0.003)} - \delta_{(\Delta=0.001)}\right)\right)} \quad (2)$$

where:

K_A = core material initial chord slope, N/mm [lbf/in.];
$P_{(\Delta=0.003)}$ = applied force corresponding to $\delta_{(\Delta=0.003)}$, N [lbf];
$P_{(\Delta=0.001)}$ = applied force corresponding to $\delta_{(\Delta=0.001)}$, N [lbf];
$\delta_{(\Delta=0.003)}$ = recorded displacement value at which Δ is closest to 0.003, mm [in.]; and
$\delta_{(\Delta=0.001)}$ = recorded displacement value at which Δ is closest to 0.001, mm [in.].

13.4 *Post-Crush Chord Slope*—Calculate K_B, the post-crush chord slope of the force versus displacement curve, working backwards from the end of the test using Eq 3 and report the results to three significant figures. Perform this calculation for all data points until the point is reached where K_B equals K_A, the initial chord slope. Determine the values of P_i, $P_{(\Delta i+0.002)}$, δ_i and $\delta_{(\Delta i+0.002)}$ for this point and report the results to three significant figures. This value of $\delta_{(\Delta i+0.002)}$ shall be designated as δ_B which shall be reported to three significant figures.

$$K_B = \frac{\left(\left(P_{(\Delta i+0.002)} - P_i\right)\right)}{\left(\left(\delta_{(\Delta i+0.002)} - \delta_i\right)\right)} \quad (3)$$

where:

K_B = core material post-crush chord slope, N/mm [lbf/in.];
P_i = applied force corresponding to δ_i, N [lbf];
$P_{(\Delta i+0.002)}$ = applied force corresponding to $\delta_{(\Delta i+0.002)}$, N [lbf];
δ_i = recorded displacement value at *i*th data point after crushing, mm [in.]; and
$\delta_{(\Delta i+0.002)}$ = recorded displacement value after crushing at which Δ is at least 0.002 greater than Δ_i (corresponding to δ_i), mm [in.].

13.5 *Onset of Crush Stroke*—Calculate K_C, the pre-crush slope of the force versus displacement curve, beyond $\delta_{(\Delta=0.003)}$ using Eq 4 and report the results to three significant figures. Perform this calculation for all data points until the point is reached where K_C equals 0.75 K_A. Determine the value of δ_j for this point. This value of δ_j shall be designated as δ_C which represents the onset of the crush stroke and shall be reported to three significant figures.

$$K_C = \frac{((P_j - P_{(\Delta=0.001)}))}{((\delta_j - \delta_{(\Delta=0.001)}))} \quad (4)$$

where:

K_C = core material pre-crush chord slope, N/mm [lbf/in.];
P_j = applied force corresponding to δ_j, N [lbf];
δ_j = recorded displacement value at *j*th data point prior to crushing, mm [in.]; and
δ_C = recorded displacement value representing the onset of the crush stroke, mm [in.].

NOTE 6—Alternatively, K_C can be calculated directly from K_A, and δ_C can be determined graphically from the force versus displacement plot.

13.6 *Completion of Crush Stroke*—Calculate K_D, the post-crush slope of the force versus displacement curve, working backwards from δ_B using Eq 5 and report the results to three significant figures. Perform this calculation for all data points until the point is reached where K_D equals 0.75 K_B. Determine the value of δ_i for this point. This value of δ_j shall be designated as δ_D which represents the completion of the crush stroke and shall be reported to three significant figures.

$$K_D = \frac{((P_B - P_i))}{((\delta_B - \delta_i))} \quad (5)$$

where:

K_D = core material post-crush chord slope for δ_D determination, N/mm [lbf/in.];
P_B = applied force corresponding to δ_B, N [lbf];
δ_B = recorded displacement value of $\delta_{(\Delta i+0.002)}$ as designated in 13.4, mm [in.]; and
δ_D = recorded displacement value representing the completion of the crush stroke, mm [in.].

NOTE 7—Alternatively, K_D can be calculated directly from K_B, and δ_D can be determined graphically from the force versus displacement plot.

13.7 *Crush Stroke*—Calculate the flatwise crush stroke using Eq 6 and report the results to three significant figures.

$$\delta_{cr} = \delta_D - \delta_C \quad (6)$$

where:

δ_{cr} = crush stroke, mm [in.].

13.8 *Crush Stroke in Percent*—Calculate the flatwise crush stroke in percent using Eq 7 and report the results to three significant figures.

$$s_{cr} = \left(\frac{\delta_{cr}}{t_i}\right) \times 100 \quad (7)$$

where:

s_{cr} = crush stroke in percent [%.].

13.9 *Crush Stress*—Calculate the average flatwise crush stress using Eq 8 and report the results to three significant figures. Honeycomb core materials typically demonstrate relatively constant crush force/stress levels between 25 and 75 % of the crush stroke.

$$\sigma_{cr} = \frac{P_{cr}}{A} \quad (8)$$

where:

σ_{cr} = average flatwise compressive crush stress, MPa [psi];
P_{cr} = average applied crush force, between 25 and 75 % of the crush stroke (see Fig. 6), N [lbf]; and
A = cross-sectional area, mm^2 [$in.^2$].

13.10 *Statistics*—For each series of tests calculate the average value, standard deviation, and coefficient of variation (in percent) for crush stress and crush stroke:

$$\bar{x} = \frac{\left(\sum_{i=1}^{n} X_i\right)}{n} \quad (9)$$

$$S_{n-1} = \sqrt{\frac{\left(\sum_{i=1}^{n} x_i^2 - n\bar{x}^2\right)}{(n-1)}} \quad (10)$$

$$CV = 100 \times \frac{S_{n-1}}{\bar{x}} \quad (11)$$

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 honeycomb sandwich core 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 core material including: fabrication start date, fabrication end date, process specification, and a description of the equipment used.

14.1.6 If requested, core material density test method, specimen sampling method and geometries, test parameters and test results.

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

14.1.8 Results of any nondestructive evaluation tests.

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

14.1.10 Details of loading platens and apparatus, including dimensions and material(s) used.

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

14.1.12 Type, range and sensitivity of displacement indicator, LVDT or compressometer, or any other instruments used to measure loading platen deflection.

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 Conditioning parameters and results.

14.1.16 Relative humidity and temperature of the testing laboratory.

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

14.1.18 Number of specimens tested.

14.1.19 Method of pre-crushing (if performed) and description of pre-crush device.

14.1.20 Speed of testing.

14.1.21 Individual crush strokes, crush stroke in percent, and average value, standard deviation, and coefficient of variation (in percent) for the population.

14.1.22 Individual average crush stress and average value, standard deviation, and coefficient of variation (in percent) for the population.

14.1.23 Individual values of K_A, K_B, K_C, K_D, δ_B, δ_C, and δ_D for each specimen.

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

14.1.25 Force versus recorded LVDT/compressometer deflection data and normalized deflection values for each specimen so evaluated.

14.1.26 Failure mode 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 method as no acceptable reference standards exist.

16. Keywords

16.1 core material; crush stress; crush stroke; flatwise compression; honeycomb; sandwich