Designation: C 480/C 480M – 08

Standard Test Method for Flexure Creep of Sandwich Constructions[1]

This standard is issued under the fixed designation C 480/C 480M; 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 determination of the creep characteristics and creep rate of flat sandwich constructions loaded in flexure, at any desired temperature. 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 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.

1.3 *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
C 393/C 393M Test Method for Core Shear Properties of Sandwich Constructions by Beam Flexure
D 883 Terminology Relating to Plastics
D 3878 Terminology for Composite Materials
D 5229/D 5229M Test Method for Moisture Absorption Properties and Equilibrium Conditioning of Polymer Matrix Composite Materials
D 7249/D 7249M Test Method for Facing Properties of Sandwich Constructions by Long Beam Flexure
E 6 Terminology Relating to Methods of Mechanical Testing
E 122 Practice for Calculating Sample Size to Estimate, With Specified Precision, the Average for a Characteristic of 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

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 terminology documents.

3.2 *Symbols:*

3.2.1 *A*—distance between pivot point and point of applied force on the specimen

3.2.2 *b*—specimen width

3.2.3 *B*—distance from pivot point to center of gravity of the loading arm

3.2.4 *c*—core thickness

3.2.5 CR_I—creep rate at time, i_i

3.2.6 *d*—sandwich total thickness

3.2.7 *d*—initial static deflection under the same load and at the same temperature

3.2.8 *D*—total deflection at time, *t*

3.2.9 F_f—applied facing stress

3.2.10 F_s—applied core shear stress

3.2.11 *M*—distance between point and weight point

3.2.12 *n*—number of specimens

3.2.13 *p*—mass of loading plate and rod

3.2.14 *P*—applied force

3.2.15 *S*—length of support span

3.2.16 *w*—mass of lever arm

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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.

3.2.17 *W*—mass of weight (including tray mass)

4. Summary of Test Method

4.1 This test method consists of subjecting a beam of sandwich construction to a sustained force normal to the plane of the sandwich, using either a 3-point or a 4-point loading fixture. Deflection versus time measurements are recorded.

4.2 For long beam specimens conforming to Test Method D 7249/D 7249M, the only acceptable failure modes for sandwich facesheet strength are those which are internal to one of the facesheets. Failure of the sandwich core or the core-to-facesheet bond preceding failure of one of the facesheets is not an acceptable failure mode for this specimen configuration.

4.3 For short-beam specimens conforming to Test Method C 393/C 393M, the only acceptable failure modes are core shear or core-to-facing bond. Failure of the sandwich facing preceding failure of the core or core-to-facing bond is not an acceptable failure mode for this specimen configuration.

4.4 Careful post-test inspection of the specimen is required as facing failure occurring in proximity to the loading points can be caused by local through-thickness compression or shear failure of the core that precedes failure of the facing.

5. Significance and Use

5.1 The determination of the creep rate provides information on the behavior of sandwich constructions under constant applied force. Creep is defined as deflection under constant force over a period of time beyond the initial deformation as a result of the application of the force. Deflection data obtained from this test method can be plotted against time, and a creep rate determined. By using standard specimen constructions and constant loading, the test method may also be used to evaluate creep behavior of sandwich panel core-to-facing adhesives.

5.2 This test method provides a standard method of obtaining flexure creep of sandwich constructions for quality control, acceptance specification testing, and research and development.

5.3 Factors that influence the sandwich construction creep response 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, core thickness, 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. Further, facing and core-to-facing strength and creep response may be different between precured/bonded and co-cured facesheets of the same material.

6. Interferences

6.1 The interferences listed in Test Methods C 393/C 393M and D 7249/D 7249M are also applicable to this test method.

7. Apparatus

7.1 *Micrometers and Calipers*—A micrometer having a flat anvil interface, or a caliper of suitable size, shall be used. The instruments(s) shall have an accuracy of ±25 µm [±0.001 in.] for thickness measurement, and an accuracy of ±250 µm [±0.010 in.] for length and width measurements.

NOTE 1—The accuracies given above are based on achieving measurements that are within 1 % of the sample length, width and thickness.

7.2 *Loading Fixtures*—The fixture for loading the specimen shall be a 3-point loading configuration that conforms to either Test Method D 7249/D 7249M (for a long beam test) or to Test Method C 393/C 393M (for a short beam test) except that a constant force shall be applied by means of weights and a lever system. Fig. 1 shows a lever and weight-loading apparatus that has been found satisfactory.

7.3 *Deflectometer (LVDT)*—The deflection of the specimen shall be measured in the center of the support span by a properly calibrated device having an accuracy of ±0.025 mm [±0.001 in.] or better.

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 (a minimum of once daily checks are recommended).

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, Facing, Core*:

8.2.1 *Core or Core-to-Facing Failure Mode Desired*—The test specimen configuration shall be a sandwich construction of a size and proportions conforming to the flexure test specimen described in Test Method C 393/C 393M. The standard specimen configuration should be used whenever the specimen design equations in Section 8.2.3 of C 393/C 393M indicate that a core of core-to-facing bond failure mode is expected. In

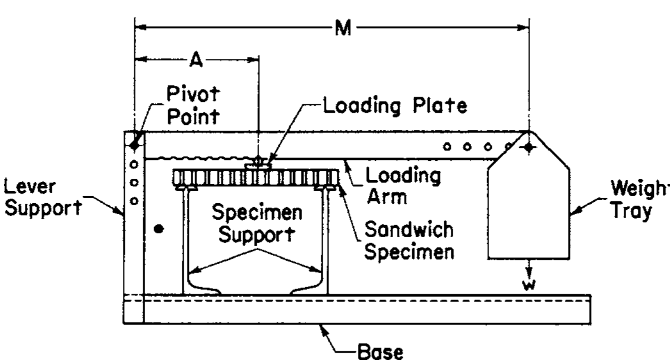

FIG. 1 Creep Test Apparatus and Loading System

cases where the standard C 393/C 393M specimen configuration will not produce a desired failure, a non-standard specimen shall be designed to produce a core or bond failure mode.

8.2.2 *Facesheet Failure Mode Desired*—The test specimen configuration shall be a sandwich construction of a size and proportions conforming to the flexure test specimen described in Test Method D 7249/D 7249M. A non-standard 3-point loading specimen configuration shall be designed per Section 8.2.3 of D 7249/D 7249M to achieve a facing failure mode. The standard 4-point loading D 7249/D 7249M specimen configuration may be used if a suitable creep loading apparatus is used.

8.3 *Compression Side Facing*—Unless otherwise specified by the test requestor, the bag-side facing of a co-cured composite sandwich panel shall be placed as the upper, compression-loaded facing during test, as facing compression strength is more sensitive to imperfections typical of bag-side surfaces (for example, intra-cell dimpling) than is facing tension strength. Creep response is expected to follow the same trends as static strength.

8.4 *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 coated machining tools 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.

8.5 *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 per D 5229/D 5229M; however, if the test requestor does not explicitly specify a pre-test conditioning environment, conditioning is not 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 2—The term moisture, as used in Test Method D 5229/D 5229M, 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 loading fixture support span (and loading span if a 4-point loading configuration is used).

11.1.3 The force, *P*, to be applied to the specimen and the maximum time for the test.

11.1.4 The properties and data reporting format desired.

11.1.5 The environmental conditioning test parameters.

11.1.6 The nominal thicknesses of the facing materials.

NOTE 3—Determine specific material property, accuracy, and data reporting requirements prior to test for proper selection of instrumentation and data recording equipment. Estimate the maximum specimen deflection to aid in transducer selection, calibration of equipment, and determination of equipment settings.

11.2 *General Instructions*:

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

11.2.2 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.

11.2.3 Before testing, measure and record the specimen length, width and thickness at three places in the test section. Measure the specimen length and width with an accuracy of ±250 µm [±0.010 in.]. Measure the specimen thickness with an accuracy of ±25 µm [±0.001 in.]. Record the dimensions to three significant figures in units of millimeters [inches].

11.3 Measure and record the length of the support and loading spans.

11.4 The weight required to apply the specified force to the specimen by the 3-point loading lever system shown in Fig. 1 may be calculated as follows:

$$W = \frac{(P - p)\,A - wB}{M} \tag{1}$$

where:

W = mass of weight (including tray mass), N [lb],
P = force applied to specimen, N [lb],
p = mass of loading plate and rod, N [lb],
w = mass of lever arm, N [lb],
A = distance between pivot point and point of applied force on the specimen, mm [in.].
B = distance from pivot point to center of gravity of the loading arm, mm [in.], and
M = distance between pivot point and weight point, mm,

11.5 *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.

11.6 *Specimen Insertion and Alignment*—Place the specimen into the test fixture. Align the fixture and specimen so that the longitudinal axis of the specimen is perpendicular (within 1°) to the longitudinal axes of the loading bars, and the bars are parallel (within 1°) to the plane of the specimen facings.

11.7 *Transducer Installation*—Attach the deflection transducer (LVDT) to the fixture and specimen, and connect to the recording instrumentation. Remove any remaining preload and balance the LVDT.

11.8 *Force Application*—Attach the weight tray to the lever arm and support it temporarily so that no force is applied to the specimen. If the test is to be conducted at an elevated temperature, place the apparatus and specimen in the oven and bring the oven up to the desired test temperature. Allow sufficient time for the oven and specimen to stabilize at the test temperature. Remove the temporary support and apply the force slowly.

11.9 *Deflection Measurement*—Measure deflections to the nearest 0.025 mm [0.001 in.]. Read the initial deflection and record it. Take deflection readings at sufficient time intervals (Note 4) to define completely a creep curve with deflection plotted as the ordinate and time as the abscissa.

NOTE 4—A recommended procedure is to take readings at 10-min intervals for the first hour, then at hourly intervals up to 7 h. After this, readings may be taken at any desired interval, such as twice a day, until the total test time has been reached or failure has occurred.

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 in one or both of the facings for a short beam C 393/C 393M type test, or occurring in the core in a long beam D 7249/D 7249M type tests, shall be cause to reexamine the loading and specimen geometry.

12.3 Contact between the loading arm and the test specimen, or contact between the weight tray and the test fixture, shall constitute an invalid test and shall be cause to reexamine the loading and test fixture.

13. Calculations

13.1 *Creep Deflection Rate*—For each pair of consecutive deflection measurements, calculate the creep deflection rate in millimetres [inches] per hour or millimetres [inches] per day for any portion of the curve (beyond the initial deformation) by obtaining the difference of the two deflections and dividing by the period of time.

$$CR_i = (D_{i+1} - D_i) / (t_{i+1} - t_i) \quad (2)$$

where:

CR_I = creep rate at time t_i,
D = total deflection at time, t, mm [inch], and
t = time.

13.2 *Creep Deflection Percentage*—For comparison of materials, the creep deflection may be expressed as a percentage of the initial deflection after a period of time as follows:

$$\text{Creep at time } t_{Ai} \text{ \% of original deflection} = \frac{D - d}{d} \times 100 \quad (3)$$

where:

D = total deflection under constant load at time t, mm [in.] and
d = initial static deflection under the same load and at the same temperature, mm [in.].

13.3 *Average Core Shear Stress*—Calculate the applied core shear stress using Eq 4:

$$F_s = \frac{P}{(d + c)b} \quad (4)$$

where:

F_s = core shear stress, MPa [psi],
b = sandwich width, mm [in.].
c = core thickness, mm [in.] ($c = d - 2t$); and
d = sandwich thickness, mm [in.];
t = nominal facing thickness, mm [in.];

NOTE 5—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 thicknesses to be used for the calculations in this test method. For precured 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.

NOTE 6—The first order approximation to the shear stress distribution through-the-thickness of a thin facesheet sandwich panel uses a linear distribution of shear stress in the facesheets starting at zero at the free surface and increasing to the core shear stress value at the facesheet-core interface. Therefore, the effective area of transverse shear stress is the core thickness + ½ of each facesheet thickness, which is equal to $c + t_1/2 + t_2/2 = (d + c)/2$.

13.4 *Facing Stress*—Calculate the applied facing stress using Eq 5and report the results to three significant figures. Eq 5 is valid for specimens with equal or unequal facing thicknesses, provided that (a) the facing thicknesses are small relative to the core thickness [$t/c \leq \sim 0.10$] and (b) the longitudinal modulus of the facings is much larger than the core modulus. For specimens with unequal facing thicknesses, calculate and report a separate facing ultimate stress for each facing, using the corresponding facing thickness.

$$F_f = \frac{PS}{2(d + c)bt} = \frac{PS}{4(d - t)bt} \quad (5)$$

where:

F_f = facing stress, MPa [psi], and
S = support span length, mm [in.].

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 7—Guides E 1309 and E 1434 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 constituent to the sandwich panel specimen tested (including facing, adhesive and core materials), 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. Description of the core orientation.

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

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

14.1.7 Results of any nondestructive evaluation tests.

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

14.1.9 Details of loading apparatus, including, support span dimensions, loading bar details and material(s) used.

14.1.10 Type, range and sensitivity of LVDT, or any other instruments used to measure loading platen deflection.

14.1.11 Measured lengths, widths and thicknesses for each specimen.

14.1.12 Weight of specimen, if requested.

14.1.13 Conditioning parameters and results.

14.1.14 Relative humidity and temperature of the testing laboratory.

14.1.15 Environment of the environmental chamber (if used) and soak time at environment.

14.1.16 Number of specimens tested, and test time for each specimen.

14.1.17 Facing thicknesses used in the calculations.

14.1.18 Facing stress and core shear stress calculated for the applied load,

14.1.19 Initial deflection at time t=0 for each specimen.

14.1.20 Creep deflection versus time curve for each specimen,

14.1.21 Creep deflection rate versus time for each specimen.

14.1.22 Creep deflection percentage versus time for each specimen

14.1.23 Type and location of failure for each specimen, if any, such as excessive creep in the adhesive, core shear, and so forth. Use the failure mode codes given in Test Methods C393 and D7249.

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 bending stress; core stress; creep; creep deflection; facing stress; sandwich; sandwich construction; sandwich deflection