



AEROSPACE MATERIAL SPECIFICATION

AMS-STD-401™

Issued	1999-06
Reaffirmed	2023-04

Sandwich Constructions and Core Materials:
General Test Methods

RATIONALE

AMS-STD-401 has been reaffirmed to comply with the SAE Five-Year Review policy.

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1. SCOPE:

1.1 Scope:

This standard covers the general requirements and methods for testing sandwich core materials and for testing sandwich construction of the types used primarily in aircraft structures. This standard does not include test methods applicable only to a specific product; such test methods are included in the detailed specifications for the product.

2. APPLICABLE DOCUMENTS 1/:

The following publications, of the issue in effect on date of invitation for bids or request for proposal, form a part of this specification to the extent specified herein.

2.1 U.S. Government Publications:

Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-STD-105 Sampling Procedures and Tables for Inspection by Attributes

2.2 ASTM Publications:

Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

- ASTM C 177 Method of Test for Thermal Conductivity of Materials by Means of the Guarded Hot Plate
- ASTM C 236 Method of Test for Thermal Conductance and Transmittance of Built-up Sections by Means of the Guarded Hot Box
- ASTM C 271 Method of Test for Density of Core Materials for Structural Sandwich Constructions
- ASTM C 272 Method of Test for Water Absorption of Core Materials for Structural Sandwich Constructions
- ASTM C 273 Method of Shear Test in Flatwise Plane of Flat Sandwich Constructions or Sandwich Cores
- ASTM C 297 Methods for Tension Test of Flat Sandwich Constructions in Flatwise Plane

1/ Designations of comparable test methods of the American Society for Testing and Materials (ASTM) are given, where they exist, for reference information. The methods specified herein are similar in techniques and procedures to the ASTM methods but are frequently more restricted in scope to include tests specifically applicable to sandwich constructions for aircraft.

2.2 (Continued):

- ASTM C 363 Method of Test for Delamination Strength of Honeycomb Type Core Material
- ASTM C 364 Method of Test for Edgewise Compressive Strength of Flat Sandwich Constructions
- ASTM C 365 Method of Test for Flatwise Compressive Strength of Sandwich Cores
- ASTM C 393 Method of Flexure Test of Flat Sandwich Constructions
- ASTM C 394 Method of Test for Shear Fatigue of Sandwich Core Materials
- ASTM D 1781 Method for Climbing Drum Peel Test for Adhesives

3. DEFINITIONS:

3.1 General:

The following terms are used throughout this standard and their interpretation shall be construed in accordance with the following definitions.

- 3.1.1 Sandwich: A laminar construction, consisting of thin facings bonded to a relatively thick lightweight core, resulting in a rigid and lightweight panel. In this standard, bonded means “joined by welding, brazing or adhesive.”
- 3.1.2 Core: A lightweight natural, synthetic, or fabricated material bonded between the facings of sandwich construction in order to separate the facings and to support them against buckling under stress.
- 3.1.3 Facing: One of the two outer layers which have been bonded to the core of a sandwich.
- 3.1.4 Flatwise: Describes the application of forces in a direction normal to the plane of sandwich. Thus flatwise compression and flatwise tension designate forces applied to compress the sandwich core and to pull the facings from the core, respectively. Flatwise flexure designates bending so as to produce curvature of the plane of a sheet of sandwich.
- 3.1.5 Edgewise: Describes the application of forces in directions parallel and actually in the plane of a sheet of sandwich.
- 3.1.6 Isotropic: Describes material, either facings or cores, having the same properties in all directions.
- 3.1.7 Orthotropic: Describes material, either facings or cores, having different strength and elastic properties in different directions.
 - 3.1.7.1 Orthotropic facing directions are usually described in terms appropriate to the facing composition such as warp and fill direction in cloth, for example.

- 3.1.7.2 Orthotropic core directions for the identification of the different axes for strength determinations are designated as "T," "L," and "W," which are specified for the following cores;

<u>Core</u>	<u>"T" direction</u>	<u>"L" direction</u>	<u>"W" direction</u>
Wood (End grain to facing)	Parallel to grain	Tangential to annual growth rings	Radial to annual growth rings
Honeycomb	Parallel to core flutes	Parallel to core ribbons	Perpendicular to core ribbons
Cellular Plastic	Parallel to slab or core thickness	Parallel to direction of foaming	Perpendicular to direction of foaming

These directions are further defined by the sketches of Figure 1.

4. GENERAL REQUIREMENTS:

4.1 Selection of test samples:

The number of samples to be chosen and the method of their selection depend on the purpose of the particular tests under consideration.

- 4.1.1 Design data: If tests are to be made to determine design values for cores, consideration must be given to the number of samples to be tested, and the number of specimens to be tested from each sample. It is suggested that at least 12 samples be tested to furnish average values and standard deviation to indicate variability and reliability of the data for selecting appropriate design values. The average values, number of tests, and standard deviation shall be reported.

4.1.2 Quality assurance provisions:

- 4.1.2.1 Sampling for the various inspections, examinations and tests: Where the inspection lot consists of a number of supposedly identical items, the provisions of MIL-STD-105 apply and should be referenced. The inspection level and Acceptable Quality Level (AQL) to be used will depend upon the expense and importance of the tests involved.

If the inspection lot is of such a nature that MIL-STD-105 should not be used, then not less than five (5) specimens of a given type shall be tested for lot acceptance, with a clear statement of what shall constitute acceptance or rejection of the lot.

When appropriate, variables sampling plans may be used instead of attribute plans.

4.2 Test conditions:

The conditions of test depend on the purpose of the particular tests under consideration and should be stipulated in the procurement specification for the material. Normal or room temperature tests shall be conducted at $73 \pm 2^\circ \text{F}$ ($23 \pm 1^\circ \text{C}$) and 50 ± 4 percent relative humidity. If the physical properties of the materials being tested are affected by moisture, the test specimens shall be brought to constant weight before testing, preferably in a conditioning chamber with temperature and humidity control. The tests shall preferably be made in a room under the same conditions. This would provide specimens having a uniform moisture content, and changes in moisture content would not occur during test.

Care shall be taken in processing specimens which may have been exposed to high humidity and conditions other than normal. Specimens to which loading fittings are bonded should be conditioned prior to bonding the fittings otherwise conditioning may not penetrate to the entire specimen. The fittings should then be bonded to the specimens under the exposure conditions so as to avoid changing the state of the specimen as would be done by bonding a wet specimen in a hot press, for example.

In conducting tests at high or low temperatures the specimen should be maintained at the desired temperature until thermocouple readings taken within the specimen show constant temperature throughout the specimen. A check on one or two specimens will usually indicate how much time is needed for attaining equilibrium conditions.

4.3 Test apparatus:

Apparatus for performing specific tests is described in the detailed test method and special apparatus for certain materials is described in procurement specifications for the material. General requirements presented here shall be met by apparatus for any tests. Measuring equipment for determining specimen dimensions and weights shall not be in error by more than $\pm 1/2$ percent. The testing machine shall measure loads within ± 1 percent of the true load applied. Mass inertia effects of machine fixtures and specimens shall be properly accounted for in calibration of repeated loading test machines so that loading is correct in the load range and machine speeds being used. The speed of the testing machine shall not deviate by more than 25 percent from the specified rate. Strain gages shall measure strains within ± 1 percent of their readings. Specific test methods may specify smaller allowable errors but the errors specified here shall not be exceeded in any test. Apparatus for tests, at elevated temperature, should be free of oils and grease and other surface contaminants that might solidify and interfere with free motion of movable parts, such as knife edges and bearings. Apparatus should be made of materials that can withstand long exposure to the elevated temperature without serious deterioration. Stainless steel has been found satisfactory for temperatures up to 1600°F (870°C). Heating can be done in an oven at the milder temperatures, but it will be found advantageous to use radiant heat sources, such as quartz lamps, at higher temperatures.

4.4 Report of test results:

The report of each test shall include a complete description of the material tested. Cores shall be described in detail as to the type of material configuration, orientation, and density. Descriptions of sandwich constructions shall include the type, size, and orientation of the facings, the procedure and materials used to bond the facings to the core, and detailed description of the core and its orientation.

The report shall give information on the previous conditioning of test specimens and the conditions during testing.

The report shall include a description of the testing machine and testing apparatus used to measure deformations or deflections.

The report shall include a brief description of testing procedures and shall give detailed descriptions and discussions of procedures which differ from those prescribed in this Standard.

Test results shall be presented in concise form including tables of data, diagrams and graphs, where necessary, and descriptions of test failures, including photographs, if necessary.

4.5 Designation of units of measurement:

Dimensions, weights, forces, and temperatures are given in U.S. Customary Units and in International Units SI. Values given in the Standard might not be converted literally, but are rounded for convenience and to correspond to accuracy of available measuring instruments.

5. DETAIL TEST METHODS:

5.1 Core test methods:

5.1.1 Core Density and Specific Gravity (ASTM C 271):

5.1.1.1 Scope: The method describes a test procedure for determining the apparent density and specific gravity of cores of sandwich construction.

5.1.1.2 Test specimens: The test specimens may be any convenient size or shape of core material that can be accurately measured. The number of test specimens shall be determined in accordance with 4.1. The test conditions shall conform to 4.2.

5.1.1.3 Test procedure: The test specimens shall be weighed to an accuracy of ± 0.5 percent and the dimensions measured within an accuracy of ± 0.5 percent.

- 5.1.1.4 Calculations: The following formulas shall be used to calculate the core density in pounds per cubic foot:

$$\text{Density (lb/ft}^3\text{)} = \frac{\text{wt (lb)}}{\text{vol (ft}^3\text{)}} = 1728 \frac{\text{wt (lb)}}{\text{vol (in.}^3\text{)}} = 3.81 \frac{\text{wt (gm)}}{\text{vol (in.}^3\text{)}} = 62.4 \frac{\text{wt (gm)}}{\text{vol (cm}^3\text{)}}$$

Specific gravity shall be calculated as follows:

$$\text{Apparent Specific Gravity} = \frac{\text{Density lb/ft}^3}{62.4}$$

- 5.1.1.5 Report: In addition to the general report requirements of 4.4, the test report shall give the individual and average core density in pounds per cubic foot.

5.1.2 Core Moisture Sorption (ASTM C 272):

- 5.1.2.1 Scope: This method describes a test procedure for determining the sorption of water by core materials when immersed.
- 5.1.2.2 Test specimen: The test specimen shall be 3 inches square and 1/2 inch thick (75 mm by 75 mm by 12 mm). The thickness of the specimen shall be in the same direction as the core thickness when used in sandwich construction. The test specimens shall be machined, sawed, or sheared from the core samples so as to have smooth surfaces which are free from cracks. The number of test specimens shall be determined in accordance with 4.1. Specimens shall be conditioned in accordance with 4.2.
- 5.1.2.3 Test procedure: The conditioned specimens shall be weighed to an accuracy of ± 0.5 percent, and then completely immersed to a depth of 1 to 2 inches (25 to 50 mm) in distilled water, maintained at a temperature of $73 \pm 2^\circ \text{ F}$ ($23 \pm 1^\circ \text{ C}$). Specimens which float shall be held under water by a loose net or screen, weighted just enough to submerge the specimens. The specimens shall be removed from the water and weighed after increasing periods of immersion so as to determine the moisture sorption - time curve for 60 days. Upon removal of specimens from the water, one at a time, all surface water shall be wiped off with a dry cloth and the specimen weighed immediately. For cores that tend to trap water in surface pores or core cells, the specimen should be dipped in absolute alcohol, dried quickly in a gentle current of warm air, and weighed immediately. If a core material is known or suspected to contain any appreciable amounts of water-soluble ingredients, the specimens of this core shall be reconditioned at 50 ± 4 percent relative humidity at $73 \pm 2^\circ \text{ F}$ ($23 \pm 1^\circ \text{ C}$) to obtain the amount of dissolved material, as determined by difference in weight of originally conditioned and reconditioned specimens.

5.1.2.4 Report: In addition to the general report requirements of 4.4, the test report shall include:

- (a) Moisture sorption data presented as a graph of percent water sorption versus time in days.
- (b) Amount of water soluble material, if any, expressed as percent of original conditioned sample.

5.1.3 Core Thermal Conductivity (ASTM C 177):

Note: The referenced method describes procedures and apparatus suitable for determining thermal conductivity in the range -100° F to 500° F and 200° F to +1,300° F (-73° C to +705° C).

5.1.4 Core Compression (ASTM C 365):

5.1.4.1 Scope: This method of test describes a procedure for determining compressive properties of sandwich cores and sandwich constructions. Deformation data can be obtained; and, from a complete load-deformation curve, it is possible to compute the compressive stress at proportional limit load, ultimate compressive strength, and modulus of elasticity of the core.

Core properties are usually required, for design purposes, in a direction normal to the plane of facings as the core would be placed in a sandwich construction, and the test procedure pertains to compression in this direction in particular, but also can be applied to determining compression properties in other directions.

5.1.4.2 Test specimens: Flatwise compression specimens shall be of core or of sandwich and shall have a minimum 2- by 2-inch (5- by 5-cm) cross section. The height of the specimens shall be not greater than 8 inches (20 cm) nor less than 1/2 inch (12 mm). Edgewise compression specimens of core (not sandwich) shall be at least 2 inches by 3/8 inch (5- by 1-cm) in cross section and shall be not greater in height than 4 times the smallest cross-sectional dimension. The dimensions of the specimens shall be measured to an accuracy of at least 0.5 percent. The number of specimens shall be determined in accordance with 4.1. The specimens shall be conditioned in accordance with requirements of 4.2.

5.1.4.3 Specimen preparation: Care shall be taken to prepare the test specimens so that the loaded ends will be parallel to each other and perpendicular to the sides of the specimen. In order to avoid local crushing at the ends of some cores in flatwise compression, particularly honeycomb and gridded cores, it is desirable to reinforce the ends with a suitable material. The ends may be cast in a molding material, such as plaster of Paris or cast resin, or they may be dipped in a thin layer of resin (epoxy resin has been found to be satisfactory) and cured at room temperature or slightly elevated temperature. The resin-dipping procedure results in leaving openings at the ends of the cells of the specimen, thus allowing circulation of exposure media if such exposures are to be made. It has been found that a resin dip, as shallow as 1/16 inch (2 mm), will provide adequate support for many types of cores so as to prevent localized end failures.

- 5.1.4.4 Test procedure: The load shall be applied to the specimen through a spherical loading block, preferably of the suspended, self-aligning type. Care shall be taken so that the block shall apply load as uniformly as possible over the entire loading surface of the specimen. The load shall be applied at a constant rate of movement of the movable head of the testing machine (Note 1) and at such a rate that the maximum load (Note 2) will occur between 3 and 6 minutes.

Note 1: A suggested rate of head movement is 0.3 percent of core height, per minute.

Note 2: For cores that continue to compress and have no definite maximum load, the maximum load shall be the load at 2 percent strain, or if head movement is measured, the maximum load shall be the load at 10 percent total compression.

Data for stress-strain curves may be taken. For determining strains, deformations shall be measured to at least the nearest 0.0001 inch (0.002 mm) by means of a compressometer, having a gage length not exceeding 2/3 of the height of the specimen. The compressometer shall measure average deformations (measurements can be taken on two opposite sides of the specimen and averaged) over the central portion of the height of the specimen. The compressometer shall be light in weight, require a minimum force to operate, and shall be attached in such a way that it will not damage or stiffen the specimen, thus producing incorrect results. Increments in load should be chosen so that at least 12 readings of deformation are taken to proportional limit.

A Marten's mirror-type of strain gage, a Tuckerman strain gage, or a microformer type, with autographic recorder, have been found to work satisfactorily for most cores. For honeycomb cores having cells smaller than 1/2 inch (12 mm), it has been found that properties of specimens 1/2 inch (12 mm) in height are no different than for specimens 4 or 8 inches (10 or 20 cm) long; thus, a long specimen can be tested using a long gage length and, in general, a more practical, simpler test will result than if short 1/2-inch (12-mm) specimens are tested. For extremely soft cores, it has been found necessary to measure strains with Filar microscopes, focused on points of fine needles inserted in the core. Bonded electric resistance strain gages are usually not considered satisfactory for soft cores because of the stiffness of the gage. The reinforcing effect of bonding these gages to some cores leads to large errors in actual strain measurement.

Note: The use of dial gages for measuring head movement to obtain strains is not as accurate as, nor exactly comparable to, the use of strain gages mounted on the specimen. Such measurements of total compression, interpreted as strains, lead to value of moduli of elasticity having considerable variation, and to values perhaps only 1/10 of the values as correctly obtained by measuring directly on the specimen. Also, proportional limit loads will be greater if head movement is interpreted as strain, thus leading to unconservative proportional limit stresses.