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Fibre-reinforced plastic composites — Determination of compressive properties in the in-plane direction

Composites plastiques renforcés de fibres — Détermination des caractéristiques en compression dans le plan

Reference number
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Contents

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 14126 was prepared by ISO/TC 61, *Plastics*, Subcommittee SC 13, *Composites and reinforcement fibres*.

This first edition cancels and replaces ISO 8515:1991, which dealt only with glass-fibre-reinforced plastic composites.

Annex A forms a normative part of this International Standard. Annexes B to D are for information only.

Introduction

This standard is based on ISO 8515, with the scope extended to include all fibre-reinforced plastic composites, such as more recent composites based on carbon and aramid fibres, but retains the test conditions relevant for glass-fibre-reinforced systems. Other source documents consulted include ASTM D 3410 (buckling criteria, larger specimen width and longer gauge length), ASTM D 695 (modified version in SACMA SRM1), prEN 2850, CRAG 400, DIN 65380 and JIS K 7076 (see bibliography).

Several different types of jig, different materials and different specimen sizes are covered by these source documents. The table below presents examples, the specimen sizes being given as overall length × gauge length × width × thickness, in millimetres.

ISO 8515 (GRP)	Celanese type 110 × 13 × 6,4 × 2	End block 120 × 20 × 10 × (3 to 10)	
prEN 2850 (CFRP)	Celanese type 110 × 10 × 10 × 2	ASTM D 695 80 × 5 × 12,5 × 2	Revision includes a machined specimen with co-cured tabs.
JIS K 7076 (CFRP)	ASTM D 695 78 × 8 × 12,5 × 2	Celanese 134 × 8 × 6,5 × 2	ITTRI 108 × 8 × (6 to 12,5) × (1 to 2)
ASTM D 3410 (all fibres)	Celanese 140 × 12 × 6 × variable	ITTRI 140 × (25 to 12) × (12 or 25) × variable	
(equations/tables give required thickness for modulus, expected strength and gauge length)			
DIN 65380 (all fibres)	Celanese 112 × 8 × 6,35 × 2	ITTRI 112 × 8 × 6,35 × 2	
CRAG 400 (all fibres)	Celanese 110 × 10 × 10 × 2		
SACMA SRM1 (all fibres)	ASTM D 695 (modified) 80,8 × 12,7 × 4,8 × [1 (unidir.) or 3 (fabric)]		

These test methods use aspect ratios (height/thickness and height/width) for the gauge area covering a range of values, which appears undesirable in a test known to be susceptible to buckling failures. Also, new support jigs are still being developed. This International Standard harmonizes and rationalizes the current situation by:

a) concentrating on the quality of the test by limiting the maximum bending-buckling strain allowable at failure (i.e. 10 % as recommended by ASTM — see also 5 % level in prEN 2850), so that it is possible to justify an axial-load analysis;

b) allowing any design of jig to be used that meets this above requirement, using two methods of loading (i.e. shear and end loaded);

c) standardizing on two specimen designs, one principally for unidirectional material and one for other materials (the chosen specimen can be used with either loading method);

d) adding an informative note as annex D, which was proposed by ASTM for harmonization purposes, and is taken from ASTM D 3410 (in a modified form).

Fibre-reinforced plastic composites — Determination of compressive properties in the in-plane direction

1 Scope

1.1 This International Standard specifies two methods for determining compressive properties, in directions parallel to the plane of lamination, of fibre-reinforced plastic composites.

1.2 The compressive properties are of interest for specifications and quality-control purposes.

1.3 Two loading methods and two types of specimen are described. They are:

— Method 1: provides shear loading of the specimen (gauge length unsupported).

— Method 2: provides end loading, or mixed loading, of the specimen (gauge length unsupported).

NOTE For tabbed specimens end-loaded using method 2, some load is transferred into the specimen gauge length by shear through the tabs.

— Type A specimen: rectangular cross-section, fixed thickness, end-tabbed.

— Type B specimen: rectangular cross-section, range of thicknesses, untabbed or end-tabbed (two sizes available).

Any combination of test method and specimen may be used, provided that the requirements of subclause 9.8 are satisfied and that the specimen is representative of the material under test. These alternative test conditions will not necessarily give the same result.

The type A specimen is the preferred specimen for unidirectionally reinforced materials tested in the fibre direction. For other materials, the type A or B specimen may be used. The type B2 specimen is preferred for mat, fabric and other multidirectionally reinforced materials.

1.4 The methods are suitable for fibre-reinforced thermoplastic and thermosetting plastic composites.

Unreinforced and particle-filled plastics, as well as those reinforced with short fibres (less than 1 mm in length), are covered by ISO 604 (see bibliography).

1.5 The methods are performed using specimens which may be machined from a test panel made in accordance with ISO 1268 or equivalent methods, or from finished or semi-finished products.

1.6 The methods specify required dimensions for the specimen. Tests which are carried out on specimens of other dimensions, or on specimens which are prepared under different conditions, may produce results which are not comparable. Other factors, such as the speed of testing, the support fixture used and the condition of the specimens, can influence the results. Consequently, when comparative data are required, these factors must be carefully controlled and recorded.

1.7 Fibre-reinforced plastics are usually anisotropic. It is therefore often useful to cut test specimens in at least the two main directions of anisotropy, or in directions previously specified (for example a lengthwise direction associated with the production process).

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 291:1997, *Plastics — Standard atmospheres for conditioning and testing*.

ISO 527-1:1993, *Plastics — Determination of tensile properties — Part 1: General principles.*

ISO 527-4:1997, *Plastics — Determination of tensile properties — Part 4: Test conditions for isotropic and orthotropic fibre-reinforced plastic composites*.

ISO 1268:1974, *Plastics — Preparation of glass fibre reinforced, resin bonded, low-pressure laminated plates or panels for test purposes* (under revision).

ISO 2602:1980, *Statistical interpretation of test results — Estimation of the mean — Confidence interval*.

ISO 3534-1:1993, *Statistics — Vocabulary and symbols — Part 1: Probability and general statistical terms*.

ISO 5893:1993, *Rubber and plastics test equipment — Tensile, flexural and compression types (constant rate of traverse) — Description*.

ISO 9353:1991, *Glass-reinforced plastics — Preparation of plates with unidirectional reinforcements by bag moulding*.

3 Definitions

For the purpose of this International Standard, the following definitions apply:

3.1
compressive stress
σ_c
the compressive force experienced by the test specimen at any particular moment divided by the initial cross-sectional area of the parallel-sided portion of the specimen

It is expressed in megapascals.

3.2
compressive strength
compressive failure stress
σ_{cM}
the maximum compressive stress sustained by the specimen

It is expressed in megapascals.

3.3
compressive strain
ε_c
the ratio of the decrease in the distance between the gauge marks on the parallel-sided portion of the test specimen (due to a compressive force) to the initial distance between the gauge marks

It is expressed as a dimensionless ratio or in percent.

3.4
compressive failure strain
ε_{cM}
the longitudinal compressive strain at the compressive failure stress

It is expressed as a dimensionless ratio or in percent.

3.5
modulus of elasticity in compression
chord modulus
E_c
the stress difference (σ'' minus σ') divided by the corresponding strain difference [ε'' (= 0,002 5) minus ε' (= 0,000 5)] (see subclause 10.2)

It is expressed in megapascals.

3.6
specimen coordinate axes
the coordinate axes for the material with the fibres preferentially aligned in one direction (see Figure 1)

The direction parallel to the fibre axes is defined as the "1"-direction and the direction perpendicular to the fibre axes the "2"-direction. For other materials, the "1"-direction is normally defined in terms of a feature associated with the production process, such as the long direction for a continuous-sheet process. The "2"-direction is again perpendicular to the "1" direction.

Results for specimens cut parallel to the "1"-direction are identified by the subscript "11" (e.g. E_{c11}). Similarly, results for specimens cut parallel to the "2"-direction are identified by the subscript "22" (e.g. E_{c22}).

NOTE The "1"-direction is also referred to as the 0° or longitudinal direction, and the "2"-direction as the 90° or transverse direction. More generally, the X, Y and Z (through-thickness) coordinate system for any material can be equated to the "1"-, "2"- and "3"-directions.

4 Principle

An axial force is applied to the unsupported length of a rectangular specimen held in a loading fixture, while the applied load and strain in this area are monitored. The test method concentrates on the quality of the axial deformation experienced by the specimen. Any loading fixture can be used, provided specimen failure occurs below a 10 % bending strain in the specimen.

The compressive load is applied to the material

— either by shear through end tabs (method 1);

— or by direct end loading of the specimen (method 2).

Method 2 using a tabbed specimen results in load introduction into the test area by a combination of direct compression and shear through the tabs.

NOTE It is important to realize that the test results obtained by these two methods are not necessarily comparable.

5 Apparatus

5.1 Test machine

5.1.1 General

The machine shall conform to ISO 5893 as appropriate to the requirements given in 5.1.2 and 5.1.3.

5.1.2 Speed of testing

The test machine shall be capable of maintaining the required speed of testing (see 9.5).

5.1.3 Indication of load

The error for the indicated load shall not exceed ± 1 %.

5.2 Strain measurement

Strain shall be determined by means of either strain gauges or suitable extensometers. Strain shall be measured on both faces of the specimens. Strain gauge elements shall be not more than 3 mm in length. The error for the indicated strain shall not exceed ± 1 % for type A and B1 specimens. The gauges, the surface preparation and the bonding agents used shall be chosen to give adequate performance with the materials being tested, and suitable strain-recording equipment shall be employed.

5.3 Micrometer

A micrometer, or equivalent, reading to less than or equal to 0,01 mm shall be used to determine the thickness h and width b of the test specimen.

The micrometer shall have faces appropriate to the surface being measured (i.e. flat faces for flat, polished surfaces and round faces for other cases).

5.4 Loading fixtures

5.4.1 General

Fixtures appropriate to the loading method chosen shall be used. The compression fixture shall load the specimen so that the requirement on allowable specimen bending given in 9.8 is met. The fixture used shall be identified in the test report.

5.4.2 Method 1: shear loading

The load is applied to the specimen by shear through the faces of the end tabs. It is permissible to use different types of grip and sleeve (trapezoidal, for example). Aligned hydraulic grips in aligned test machines are also acceptable. A schematic diagram of a compression fixture for shear loading is given in Figure 2.

NOTE Some method 1 fixtures in common use are shown in annex B, e.g. ASTM D 3410: method A (Celanese) and method B (ITTRI).

5.4.3 Method 2: end loading

The load is applied directly to the end of the specimen. For a tabbed specimen, loading is by a combination of end loading and shear loading through the tab. A schematic diagram of a compression fixture for shear loading is given in Figure 3.

NOTE 1 Some method 2 fixtures in common use are shown in annex C, e.g. ISO 8515 and ASTM D 695 (modified version in prEN 2850). The D 695 fixture gives a lower degree of support to the end of the specimen.

NOTE 2 The main aspect of the fixture design for both loading methods is the alignment (initial and throughout the test), and for method B of ASTM D 3410 a further important aspect is prevention of failure at the end of the specimen.

6 Test specimens

6.1 Shape and dimensions

6.1.1 Type A specimen

The specimen shall be straight-sided and of rectangular cross-section, with the dimensions given in Table 1 (see also Figure 4).

6.1.2 Type B specimen

The specimen shall be straight-sided and of rectangular cross-section, with the dimensions given in Table 1. End tabs shall be used if necessary to avoid failure at the loaded ends of the specimen.

Table 1 — Specimen dimensions

Dimensions in millimetres

Dimensions	Symbol	Type A specimen	Type B1 specimen	Type B2 specimen
Overall length (minimum)	l_0	110 ± 1	110 ± 1	125 ± 1
Thickness	h	2 ± 0,2	2 ± 0,2 to 10 ± 0,2	⩾ 4
Width	b	10 ± 0,5	10 ± 0,5	25 ± 0,5
Distance between end tabs/grips	L	10	10	25
Length of end tabs (minimum)	l_t	50	50 (if required)	50 (if required)
Thickness of end tabs	d_t	1	0,5 to 2 (if required)	0,5 to 2 (if required)

NOTE Requirements for specimen quality and parallelism of specimen and end tabs are given in subclause 6.3.

6.2 Preparation

6.2.1 General

A panel shall be prepared in accordance with ISO 1268, ISO 9353 or another specified/agreed procedure. Specimens cut from finished parts (for example, for quality control during manufacture or on delivery) shall be taken from flat areas of uniform thickness.

6.2.2 End-tab material

The ends of the specimen shall be reinforced, if necessary, with end tabs made preferably from a 0°/90° cross-ply or fabric laminate made from glass-fibre/resin with the fibre axes in the fabric set at ±45° to the specimen axis. The tab thickness shall be between 0,5 mm and 2 mm, with a tab angle of 90° (i.e. not tapered). If tab failure occurs under high end loads, the fibre axes in the tab shall be set at 0°/90° to the specimen axis.

Alternatives, such as tabs made from the material under test, mechanically fastened tabs, unbonded tabs or friction materials (emery paper, grit paper or fine-finish grip faces), shall be shown, before use, to give at least equal strength values (see ISO 527-1:1993, subclause 10.5) and no greater coefficient of variation (see ISO 3534-1) than the recommended tab material. When the test is carried out on untabbed specimens, the "distance between tabs" shall be taken to be the distance between the tabs of a corresponding tabbed specimen (see ISO 527-4:1997, type 3 specimen).

6.2.3 Application of end tabs

The end tabs shall be bonded to the specimen as shown in annex A.

NOTE This procedure can be used for individual specimens or groups of specimens.

6.2.4 Machining the specimens

Method 1: Machine the tab surfaces as necessary to ensure the tabs are symmetrical about the specimen centreline and parallel to each other.

Method 2: Machine the end faces of each specimen so that they are parallel to each other and perpendicular to the longitudinal axis of the specimen. The allowed deviation from parallel of the areas of the end-loading plates in