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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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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 13, *Composites and reinforcement fibres*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 249, *Plastics,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This second edition cancels and replaces the first edition (ISO 14126:1999), which has been technically revised.

The main changes are as follows:

— a new normative Annex A, alignment of specimen and loading train, has been added and subsequent annexes have been renumbered;

— Annex B, specimen preparation, is now normative to emphasise the importance of producing good quality specimens;

— two new informative Annexes F and G have been added.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document, originally published in 1999, was based on ISO 8515[1] with the scope extended from glass-fibre reinforcement to include all fibre-reinforced plastic composites, such as composites based on carbon and aramid fibres. Other source documents consulted included ASTM D 3410[2], SACMA SRM1[3], prEN 2850[4], CRAG 400[5], DIN 65380[6] and JIS K7076[7]. Several different types of anti-buckling fixtures/loading jigs, different materials and different specimen sizes are covered by these source documents, although all are parallel-sided coupons. New or modified geometry support jigs are still being developed, for example in JIS K7018[8].

This document harmonizes and rationalizes the current situation by:

a) concentrating on the quality of the test by limiting the maximum bending strain allowable (i.e. 10 % between 10 % and 90 % of the maximum load, as recommended by ASTM), so that an axial-load case can be assumed;

b) standardizing on two related specimen designs, one principally for aerospace type unidirectional pre-impregnated materials (i.e. Type A) and one for other materials/formats (i.e. Types B1/B2). The chosen specimen design can be used with different loading fixtures;

c) defining acceptable failure criteria (e.g. avoiding within grip failures);

d) including an equation for determining the specimen minimum thickness to avoid Euler buckling proposed by ASTM for harmonization purposes (taken from ASTM D 3410[2] in a modified form);

e) allowing any design of support/loading fixture to be used that meets the above bending requirements, using different principles of loading (i.e. essentially shear and combined loading);

f) ensuring that the test specimen and loading/support fixture are well aligned (see Annex A);

g) concentrating on the quality of specimen preparation (see Annex B);

h) including guidance on the use of digital image correlation (DIC) for strain and bending measurements (see Annex G);

NOTE 1 Compression properties measured in the through-thickness direction (direction 3 in Figure 1) are covered by ISO 20975-1[9].

NOTE 2 Compression properties of rigid plastics having only unaligned short (<7,5 mm) fibres or no fibre content [rather than long (>7,5 mm) discontinuous or continuous fibres] is covered by ISO 604[10].

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

1 Scope

1.1 This document specifies methods for determining the compressive properties, in directions parallel to the plane of lamination, of fibre-reinforced plastic composites, based on thermosetting or thermoplastic matrices. The compressive properties are of interest for specifications and quality-control purposes. The test specimens are machined from a flat test plate, or from suitable finished or semi-finished products.

1.2 Two loading methods and two types of specimen are described.

The loading methods are:

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

— Method 2: provides combined loading of the specimen (gauge length unsupported)

NOTE For tabbed specimens loaded using method 2, load is transferred through a combination of end-loading and shear-loading through the tabs.

The specimen designs are:

— Type A specimen: rectangular cross-section, fixed thickness, end-tabbed (mainly for aerospace style preimpregnates (~ 0,125 mm ply thickness)

— Type B specimen: rectangular cross-section, range of thicknesses, untabbed or end-tabbed, two specimen sizes are available (B1 and B2).

The Type A specimen is used for unidirectionally or biaxially reinforced materials tested in the fibre direction, where the fibres are normally either aligned continuous or aligned long (>7,5 mm) discontinuous. The Type B1 and B2 specimens are used for multi-directional aligned; mat, fabric and other multi-directionally reinforced materials where the fibre structure is more complex and/or coarser.

1.3 This document gives criteria for checking that the combination of test method and specimen design result in valid failures. It is noted that alternative test method/specimen combinations will not necessarily give the same result.

1.4 The methods specify required dimensions for the specimen. Tests carried out on specimens of other dimensions, or on specimens that are prepared under different conditions, can produce results that are not comparable. Other factors, such as the speed of testing, the support fixture used and the conditioning of the specimens, can influence the results.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

ISO 1268 (all parts), *Fibre-reinforced plastics — Methods of producing test plate*

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

ISO 7500-1, *Metallic materials — Calibration and verification of static uniaxial testing machines — Part 1: Tension/compression testing machines — Calibration and verification of the force-measuring system*

ISO 9513, *Metallic materials — Calibration of extensometer systems used in uniaxial testing*

ISO 23788, *Metallic materials — Verification of the alignment of fatigue testing machines*

ASTM E 1012, *Standard practice for verification of testing frame and specimen alignment under tensile and compressive axial force application*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

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

Note 1 to entry: It is expressed in megapascals.

3.2
compressive strength
compressive failure stress
σ_{cM}
maximum *compressive stress* (3.1) sustained by the specimen

Note 1 to entry: It is expressed in megapascals.

3.3
compressive strain
ε_c
decrease in length per unit length of the original gauge length

Note 1 to entry: It is expressed as a dimensionless ratio or in percent.

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

Note 1 to entry: It is expressed as a dimensionless ratio or in percent.

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

Note 1 to entry: It is expressed in megapascals.

Note 2 to entry: See 10.2.

3.6
specimen coordinate axes
1, 2, 3
orthogonal coordinate axes for material with the fibres preferentially aligned in one direction within a planar laminate.

Note 1 to entry: See Figure 1. The directions, in the plane of the laminate, parallel to the fibre axes is specified as the "1"-direction and the direction perpendicular to the fibre axes the "2"-direction. For other materials, the "1"-direction is normally specified in terms of a feature associated with the production process, such as the long or warp direction for a continuous-sheet or fabric process. The "2"-direction is again perpendicular, in the plane, to the "1" direction. The direction perpendicular to the plane is the “3” 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 2 to entry: 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.

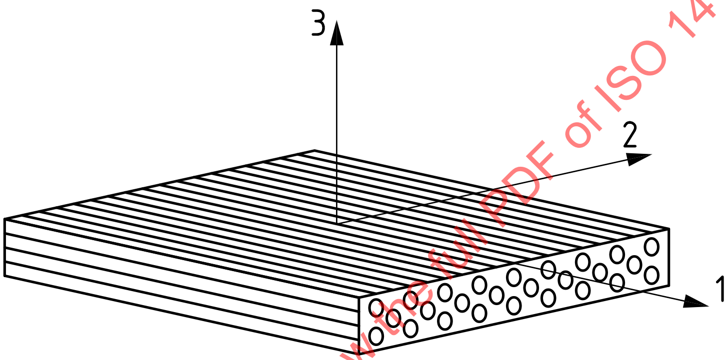


Figure 1 — Unidirectionally reinforced composite plate element showing symmetry axes

3.7
gauge length
L_0
initial distance between the gauge marks on the central part of the test specimen

Note 1 to entry: It is expressed in millimetres (mm).

3.8
thickness
h
smaller initial dimension of the rectangular cross-section in the central part of a test specimen

Note 1 to entry: It is expressed in millimetres (mm).

3.9
width
b
larger initial dimension of the rectangular cross-section in the central part of a test specimen

Note 1 to entry: It is expressed in millimetres (mm).

4 Principle

An axial force is applied to the unsupported gauge length of a rectangular specimen held in an anti-buckling loading/support fixture, while the applied load and strain in this gauge length 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 (between 10 % and 90 % of the maximum load); and fails in the prescribed manner and location.

The compressive load is applied to the specimen:

— by shear loading through end tabs (Method 1);

— by a combined loading mode through direct specimen end loading and shear loading though the support fixture using a tabbed specimen (Method 2).

NOTE 1 The test results obtained by these methods using different specimen designs/sizes and different loading fixtures are not necessarily comparable.

NOTE 2 End-loading is not covered by this document as the fixture in Method B of EN 2850[4] for end-loading (c.f. modified ASTM D695[11]) is not suitable for the standard Type A or B specimens. End loading is, in many cases, a sufficient and simple method for determination of compressive modulus but is very limited for ultimate strength determination.

NOTE 3 Each of these methods shows specific advantages and disadvantages. For example, shear loading is not adapted for very thick laminates, because it causes strain distributions over the laminate thickness caused by shear strains and the tabs can shear off at high forces. Combined loading overcomes several of the problems described before and can also be used for higher laminate thicknesses. The disadvantage is the need for supplementary machining of the specimen ends to ensure parallelism and squareness tolerances are met when using end-tabbed specimens.

5 Apparatus

5.1 Test machine

5.1.1 General

The test machine shall be in accordance with ISO 7500-1 and ISO 9513, and meet the specifications given in 5.1.2 to 5.1.3. The test machine should be kept in good condition and worn parts (e.g. threads, grip faces) replaced. The test machine, gauge specimen and loading/support fixture alignment on the machine axis shall be checked regularly or after any part of the loading train is moved/reassembled using the procedures given in Annex A.

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 Load measurement

The force measurement system shall conform with class 1 as specified in ISO 7500-1 (i.e. error for indicated load shall not exceed ±1 % of the true value). Suitable data recording equipment (data-loggers) shall be used to record the load values throughout the tests.

5.2 Strain measurement

Strain shall be determined by means of strain gauges, mechanical extensometers, or optical extensometers, [including digital image correlation (DIC)] meeting the requirement that the error for the indicated strain shall not exceed ±1 % (see ISO 9513). Strain shall be measured on both faces of the specimens to determine the degree of bending or on the sides (narrow face) of specimens if using DIC (see Annex G). Strain gauge elements for type A and B1 specimens shall be less than 3 mm in length. B2 specimens will accommodate longer strain gauges (e.g. ≥10 mm).

The gauges, the surface preparation and the bonding agents used shall be chosen to give acceptable performance with the material being tested, and suitable continuous strain recording equipment (data-logger/computer) shall be used.

NOTE Full-field strain measurements, as obtained by DIC, provide evidence for the "repeat structure" of the reinforcement[12] and therefore informs the choice of strain gauge length (i.e. larger gauge length than the size of any repeated "reinforcement structure" which causes local non-uniformity of the strain field).

5.3 Micrometer

A micrometer, caliper 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.

For thickness measurements, callipers shall have faces appropriate to the surface being measured (i.e. flat face for flat, cut or polished surfaces and hemisphere face for other surfaces) of ~6 mm diameter in both cases.

5.4 Loading fixtures

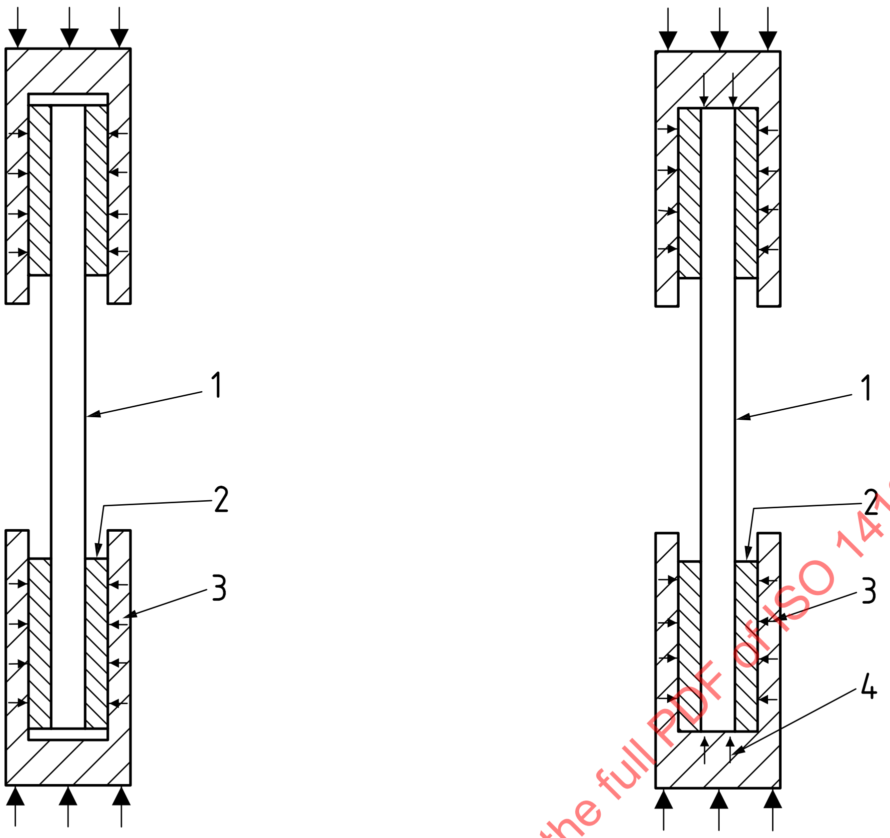
5.4.1 General

Support/loading fixtures appropriate to the loading method chosen shall be used. The fixture shall load the specimen so that the requirement on allowable specimen bending given in 9.8 is met. The main requirement of the fixture design for all loading methods is the alignment (initial and throughout the test) of the loading train and of the specimen when loaded in the fixture are maintained, so that buckling is avoided. Procedures for obtaining satisfactory alignment of the loading train are given in Annex A. The fixture used shall be fully identified and described 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 specimen end tabs. The load is applied through flat wedge or vee action grips, as shown diagrammatically in Figure 2 a). Aligned hydraulic grips in aligned test machines are also acceptable. A schematic diagram of a compression fixture for shear loading is given in Figure 3.

NOTE A Method 1 fixture in common use is shown in Annex C (i.e. ASTM D 3410: method B[2] (known as ITTRI that uses flat "back" wedge grips). An early design of this loading method known as Celanese (using cone-shaped "back" wedge grips) is no longer included in ASTM D3410[2].



a) Method 1
Shear loading

b) Method 2
Combined loading

Key

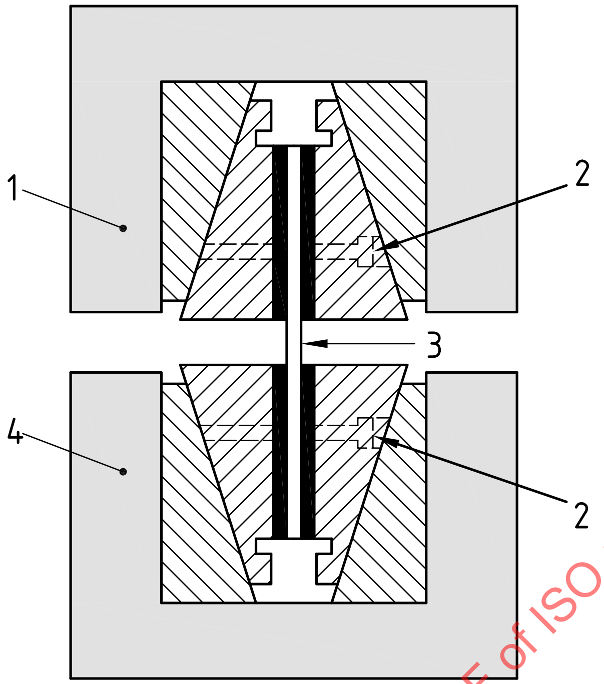
1 specimen

2 end tabs

3 shear loading

4 end loading

Figure 2 — Schematic of load condition for the alternative methods



Key

1 upper housing block

2 locking screws

3 specimen

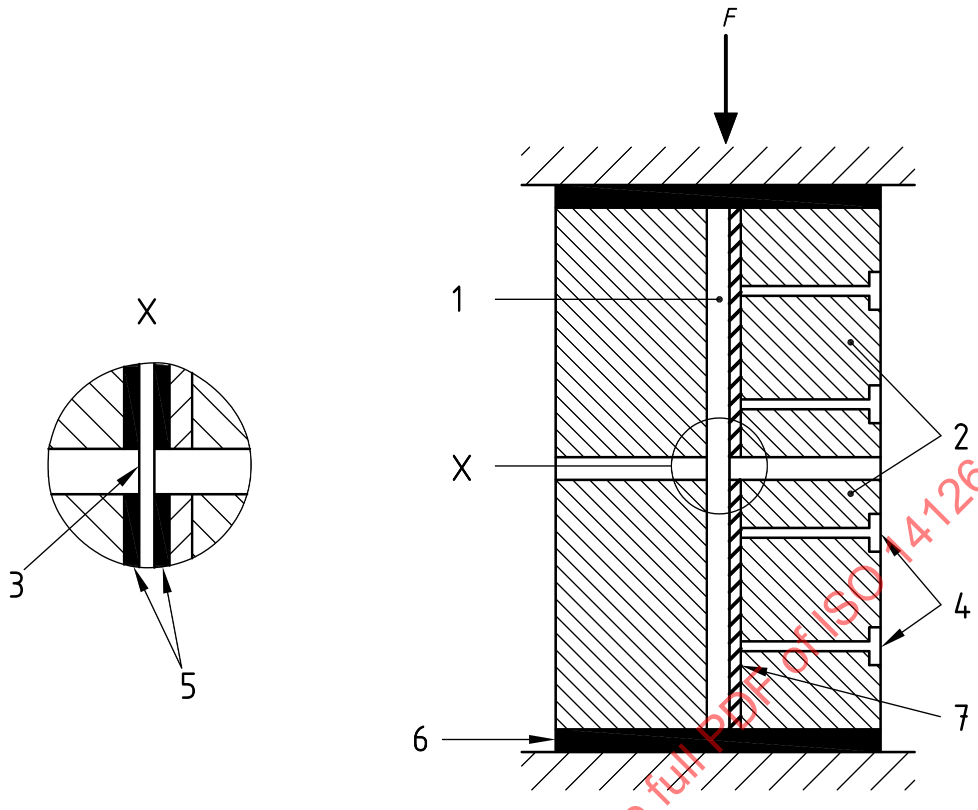
4 lower housing block

Figure 3 — Schematic diagram of compression test specimen and fixture for method 1

5.4.3 Method 2: Combined loading

Loading is by direct end loading of the specimen and by shear loading through the tab at the same time resulting in a combined loading configuration, as shown diagrammatically in Figure 2 b). A schematic diagram of a compression fixture for combined loading is given in Figure 4. Combined loading is also obtained when a supporting or anti-buckling fixture involves clamping of the specimen, although the exact loading path through the jig into the specimen gauge length is unclear. In addition, compression loading of the specimen will increase the transverse load on the bolted clamps and similar constructions due to Poisson's expansion of the specimen.

NOTE Method 2 fixtures in common use are shown in Annex D.



Key

1 specimen, untabbed (or tabbed — see insert)
2 support blocks
3 specimen
4 locking screws
5 tabs
6 end-loading plate
7 moveable face plate

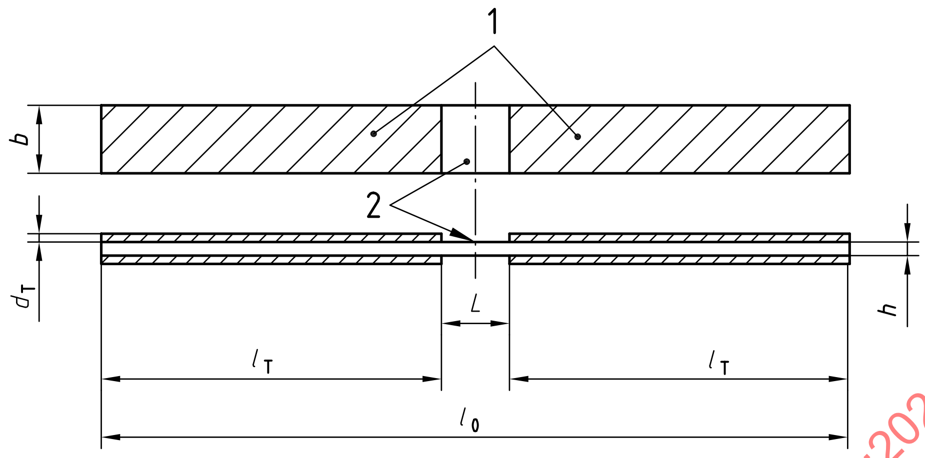
Figure 4 — Schematic diagram of compression test fixture for method 2

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 5). Type A specimens are preferred for laminates constructed from ~0,125 mm thick 0° laminae (e.g. unidirectional aerospace grade prepreg) and loaded in the 1 (axial) direction. For these unidirectionally reinforced materials, the test specimen shall be extracted with its axis within 0,5° of the mean fibre axis of the test plate.



Key

1 tabs

2 specimen

NOTE Dimensions are given in Table 1.

Figure 5 — Type A and B tabbed specimen designs

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 by distributing the applied load over the larger area of the specimen and end tabs.

Type B1 specimens are suitable for material constructed with heavier weight laminae (n.b 16 layers recommended, as used in Type A specimens with 16 layers of 0,125 mm thickness prepreg),

Type B2 specimens are suitable for "coarser" or structured fabrics [e.g. NCF (non-crimped fabrics)], multi-directional layups and 3D fabrics.

Table 1 — Specimen dimensions

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

NOTE Requirements for parallelism of specimen and end tabs are given in 6.2.4. Requirements for specimen quality are given in 6.3.

6.2 Preparation

6.2.1 General

A flat test plate shall be prepared using the appropriate fabrication route in accordance with the relevant part of the ISO 1268 series or another specified and agreed procedure. Specimens cut from finished parts (e.g. 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 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 10.4) and no greater coefficient of variation (see ISO 3534-1[13]) than the recommended tab material.

When the test is carried out on untabbed specimens, the "distance between tabs" shall be taken as, and set at, the distance between the tabs of a corresponding tabbed specimen.

NOTE 1 Further guidance is available on grip face textures and tabbing intermediates (e.g. grit/sandpaper) in ISO 527-4:2023,[14] Annex C and ISO 527-5[15].

NOTE 2 Formula (F.1) in Annex F is given to predict the minimum end tab length as a function of tab (adhesive) shear strength and expected specimen failure load.

6.2.3 Application of end tabs to specimens

The end tabs shall be bonded to the specimen as shown in Annex B. It is critical to the test result that both the tab thickness and adhesive bond-line thickness shall be of constant thickness, so that the specimen maintains a balanced symmetry (i.e. less than 5 % variation in adhesive bond thickness).

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

6.2.4 Machining the specimens

For Method 1: Machine the tab surfaces as necessary to ensure the tabs are symmetrical about the specimen centreline and parallel to each other. The ends of the two tabs either side of the specimen should be within 0,05 mm of each other at the edges of the gauge length.

For 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 contact with the specimen ends is 0,1 % of the initial full length of the specimen, i.e. the distance between the end-loading plates. Tabs, if used, shall be prepared as for Method 1 and meet the above length measurement criteria.

NOTE Additional guidance on specimen preparation is given in Annex F and in ISO 2818[16].

6.3 Checking specimen quality

The specimens, both when untabbed and tabbed, shall be free of twist and shall have symmetrical pairs of parallel surfaces. The surfaces and edges shall be free from scratches, pits, sink marks and flash. The specimens shall be checked for conformity with these requirements by visual observation against straight edges, squares and flat plates, and by measuring with micrometre callipers. Specimens showing measurable or observable departure from one or more of these requirements shall be rejected or machined to the correct size and shape before testing.

NOTE The quality of the prepared specimen has a major effect on the successful outcome of the test.

6.4 Anisotropy

The properties of fibre-reinforced plastic composites frequently vary with direction in the plane of the sheet (anisotropy). For this reason, it is recommended that two groups of test specimens be prepared with their major axes parallel and perpendicular, respectively, to the direction of some feature which is inferred from a knowledge of the structure of the material or its method of manufacture (see 3.6).

NOTE Examples of tests required to be undertaken at different orientations (i.e. 0° and 90°) in the test plate are given in ISO 10350-2[17] and ISO 20144[18].

7 Number of test specimens

7.1 At least five test specimens shall be tested in each direction of test, as required. As a minimum, 5 specimens shall be tested in the 1 direction.

The number of measurements may be more than five if greater precision of the mean value and standard deviation are required. It is possible to calculate the number of successful tests needed in an individual direction by means of the confidence interval (95 % probability, see ISO 2602).

7.2 The results from test specimens that rupture inside the grip end blocks or end tabs shall be discarded and new specimens tested in their place. Replacement specimens shall also be used if bending of the specimen exceeds the maximum value permitted in 9.8.

NOTE This test method can result in failures at the edge of the loading fixture or end tab rather than in the middle of the gauge length. These failures are acceptable, but their occurrence can be minimized by using a different type of loading fixture, tab, etc.

7.3 With batches of specimens greater than five, tests can be conducted without making two strain measurements provided that:

a) the first five specimens are shown to fail at a bending strain less than the value given in 9.8 using back-to-back strain measurements;

b) there is no change in the test conditions (i.e. batch, specimen type, test conditions, operator, test equipment, etc.);

c) the tests are conducted over a short time period without disrupting the fixture alignment. In such cases, the modulus, if required, can be obtained from a single strain measurement. The change in procedure shall be noted in the test report [see Clause 12, p)].

8 Conditioning

Condition the test specimens as specified in the International Standard for the material tested. In the absence of this information, select the most appropriate set of conditions from ISO 291, unless otherwise agreed upon by the interested parties, e.g. when testing at an elevated or reduced temperature.

9 Procedures

9.1 Conduct the test in the atmosphere specified in the International Standard for the material tested. In the absence of this information, select the most appropriate set of conditions from ISO 291, unless otherwise agreed upon by the interested parties (e.g. when testing at elevated or low temperatures).

9.2 Measure the width b of each test specimen to the nearest 0,1 mm and the thickness h to the nearest 0,02 mm. For Type B2 specimens determine the dimensions at three different locations along the gauge section. Record the average value.

9.3 Attach chosen strain measurement and recording equipment. Two strain measurements (one on each face of the specimen, i.e. back-to-back) are required to ascertain that the maximum bending strain is not exceeded (i.e. less than 10 % bending strain between 10 % and 90 % of maximum load). Euler buckling is considered to have been detected if the strain on one face reverses (decreases) while the strain on the opposite face increases rapidly.

9.4 Mount the specimen in the compression test fixture, while ensuring that any pre-strain is less than 0,05 %. Check that the strain difference between the faces across the thickness is less than 150 με, when the grips/fixture is tightened. If higher, reduce the applied strain by slow unloading of the specimen.

9.5 Set the cross-head speed to 1 mm/min ±0,5 mm/min and load the specimen to failure.

9.6 Record the load (stress) and the deformation (strain) throughout the test.

9.7 Record the maximum load attained by the specimen during the test.

9.8 Check that the test was valid (see 7.2). A test is valid if failure occurs within or at the end of the specimen gauge length. There shall be no failure (breaking) of the specimen ends when loaded by method 2.

Bending is acceptable if the difference between the strains recorded on each face of the specimen is less than 10 % bending strain between 10 % and 90 % of the maximum load such that:

$$\left| \frac{\varepsilon_{11b} - \varepsilon_{11a}}{\varepsilon_{11b} + \varepsilon_{11a}} \right| \leq 0{,}1 \quad (1)$$

where ε_{11a} and ε_{11b} are the longitudinal strains on opposite faces of the specimen.

NOTE If a large strain difference in direction (i.e. tension on one face, compression on the other) occurs prior to failure suggesting an Euler column buckling failure, Annex E can be used to calculate a revised thickness and/or gauge length for Type B specimens.

9.9 Record the primary mode of failure by reference to Figure 6.

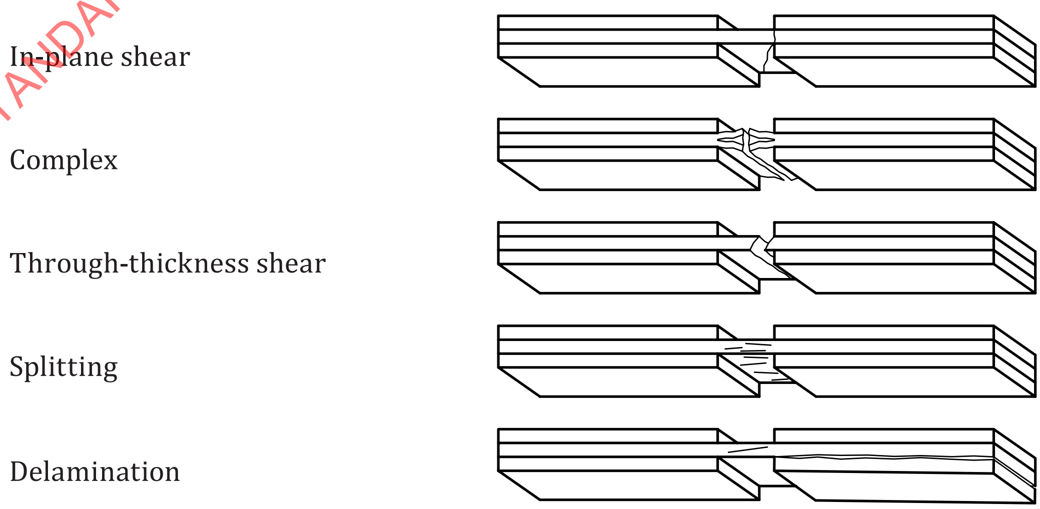


Figure 6 — Acceptable modes of failure

10 Expression of results

10.1 Compressive strength calculation

Calculate the compressive strength σ_{cM}, expressed in megapascals, using Formula (2):

$$\sigma_{cM} = \frac{F_{max}}{bh} \tag{2}$$

where

F_{max} is the maximum load, in newtons;

b is the width, in millimetres, of the test specimen;

h is the thickness, in millimetres, of the test specimen.

10.2 Compressive modulus calculation

Calculate the compressive modulus E_c, expressed in megapascals, using Formula (3):

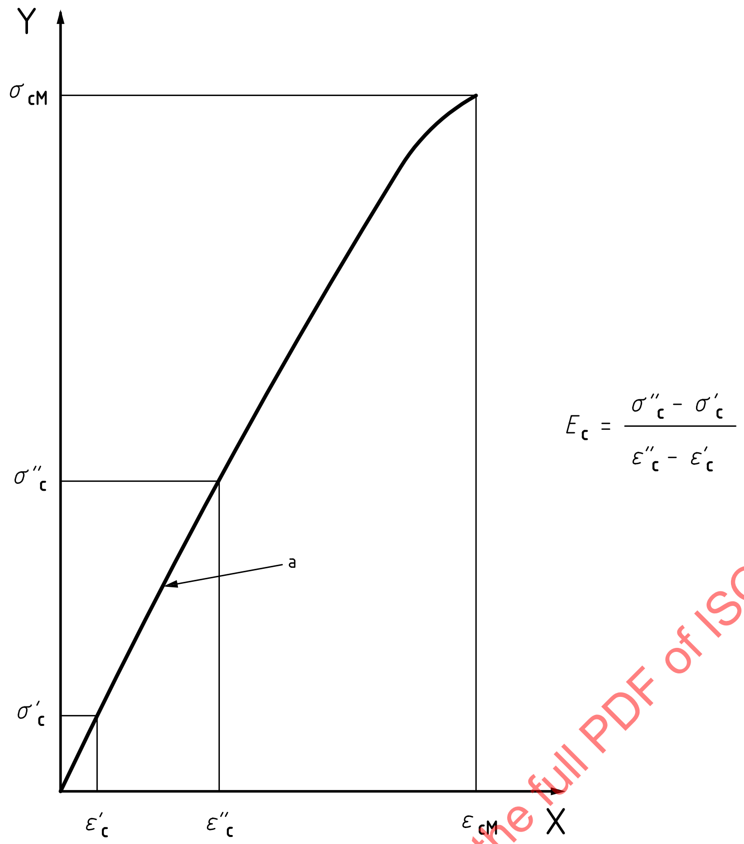
$$E_C = \frac{\sigma''_c - \sigma'_c}{\varepsilon''_c - \varepsilon'_c} \tag{3}$$

where

σ''_c is the compressive stress at $\varepsilon''_c = 0{,}002\,5$, expressed in megapascal;

σ'_c is the compressive stress at $\varepsilon'_c = 0{,}000\,5$, expressed in megapascals.

See Figure 7. $\varepsilon'_c = 0{,}000\,5$ and $\varepsilon''_c = 0{,}002\,5$ shall be average values if the strain values on opposite faces of the specimen are not equal (see 9.8).



Key

X compressive strain

Y compressive stress

a Slope = E_C

Figure 7 — Compressive stress/strain diagram

10.3 Compressive failure strain calculation

Calculate the compressive failure strain ε_{cM} from the mean of the longitudinal strains (ε_{11a} and ε_{11b}) at failure.

10.4 Statistical parameters

Calculate the arithmetic mean of the test results and, if required, the standard deviation and the 95 % confidence interval of the mean using the procedure given in ISO 2602.

10.5 Significant figures

Calculate the strength and modulus to three significant figures. Calculate the strain and Poisson's ratio to two significant figures.

11 Precision

The precision of this test method is not known because interlaboratory data are not available at the time of publication.

12 Test report

The test report shall include the following information:

a) a reference to this document (i.e. ISO 14126), indicating the loading method and specimen type used;

b) all details necessary for complete identification of the material tested, including type, source, manufacturer's code-number, form and previous history, where these are known;

c) all relevant information on the preparation of the test specimens, including information on the direction of cutting/testing (e.g. direction 1 or 2 in Figure 1);

d) all details necessary for complete identification of the loading fixture used;

e) the dimensions of the test specimens;

f) the test conditions and conditioning procedures, if applicable;

g) the number of specimens tested;

h) the speed of testing;

i) the method of strain or deformation measurement used;

j) the individual test results, if required;

k) the mean values of the individual results;

l) the type of failure obtained;

m) the standard deviations and the 95 % confidence intervals of the mean values, if required;

n) the date of measurement;

o) the name of the operator;

p) any change in the procedure from this document.

Annex A
(normative)

Alignment of specimen and loading train

The test machine and loading fixture alignment on the machine axis should be checked annually or after any part of the loading train is moved/re-assembled using the procedures given in this annex.

The alignment of the testing machine shall be checked in accordance with ISO 23788, or alternatively ASTM E 1012, in accordance with, using a rectangular alignment gauge, instrumented with strain gauges.

The result of the alignment verification depends on the dimensions of the alignment gauge being used, its stiffness and the positions of the strain gauges (or equivalent strain measurement technique being used). Therefore, the alignment gauge only reflects the expected situation when testing with specimen, if it is similar in shape, dimensions and material. Fibre-reinforced polymer composites normally show localized deformations and are therefore not adapted to serve as material for alignment gauges. Steel of a yield stress of > 800 MPa and a tensile modulus of approximately 200 GPa, free of significant internal stresses; and of similar physical dimensions is considered acceptable to represent the actual specimens.

Verify the alignment situation in at least two positions of the alignment gauge, normally turned by 180° around the centre axis of the alignment gauge. Optionally, measurements in top-down position of the alignment gauge may be required.

In accordance with ISO 23788/ASTM E 1012 it is important to:

— zero all strain values in a free hanging position of the specimen gauge and note the remaining residual bending;

— measure bending (µm/m) in clamped position at zero load or a small preload;

— measure bending (µm/m) and percent bending (%) at 1 000 microstrains (µm/m) of axial deformation;

— unload the specimen, open the lower grip and measure again the bending (µm/m) in a free hanging position to ensure that the alignment gauge was not altered during the measurement.

For static tests, percent bending shall not exceed 10 % at an axial alignment gauge deformation of 1 000 µm/m.

It is highly recommended to use specimen position end-stops in order to ensure that the specimen is placed into the grips so that the centre axis of the specimen exactly conforms to the centre axis of the testing machine.

Annex B
(normative)

Specimen preparation

B.1 Machining the specimens

In all cases, take the following precautions.

— Avoid working under conditions that creates a large build-up of heat in the specimen (the use of a coolant is recommended). If a liquid coolant is used, dry the specimens immediately after machining.

— Check that all cut surfaces of the specimen are free from machining defects.

B.2 Preparation of specimens with bonded end tabs

A recommended method is as follows:

Identify the "1"-direction of the material in the sheet.

Cut out from the material under test a sheet having the length of the intended test specimens and of a width suitable for the number of specimens required, allowing for width of all cuts made.

Cut out rectangular strips of the required length and width for the tabs. Attach the strips to the sheet as follows.

a) If required, rub with fine abrasive paper or lightly blast with suitable grit all the surfaces to which adhesive will be applied.

b) Remove all dust from these surfaces and clean them with a suitable solvent.

c) Bond the strips in place along the ends of the sheet, parallel to each other and normal to the length direction of the specimens, as shown in Figure B.1, using a high-elongation, cold-hardening adhesive (for example a two- part epoxy adhesive) and strictly following the adhesive manufacturer's instructions. Heat-curing film adhesives can also be used, provided the cure temperature is at least 40 °C below the glass transition temperature or curing temperature of the resin in the laminate, whichever is the lower.

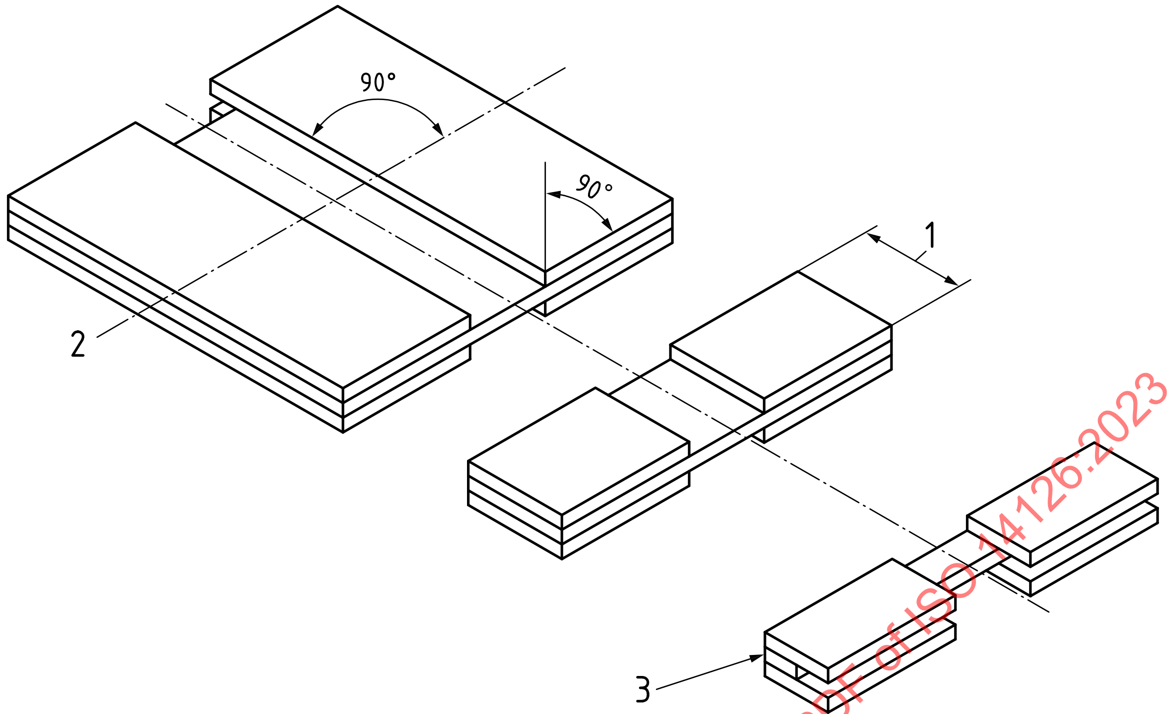
   It is recommended that a film adhesive with a thin carrier be used. The adhesive should preferably have a shear strength greater than 30 MPa. It is desirable that the adhesive used is flexible in nature, with an elongation at break greater than that of the material under test.

d) Keep the bonded parts at the pressure and temperature for the time recommended by the adhesive manufacturer.

e) Cut the sheet, together with the strips constituting the end tabs, into test specimens (see Figure B.1).

Individual specimens can be similarly prepared.

For unidirectional materials, the mean fibre axis shall be determined by splitting the edge of the test panel. The direction shall be confirmed every few specimens by repeating the operation. If splitting does not give a clean edge due to misalignment between plies or layers, the test panel should not be used unless it represents the results of a particular process or product.



Key

1 required width

2 longitudinal direction

3 trimmed to waste

Figure B.1 — Tabbed panel for specimen preparation

Annex C
(informative)

Compression fixtures for method 1

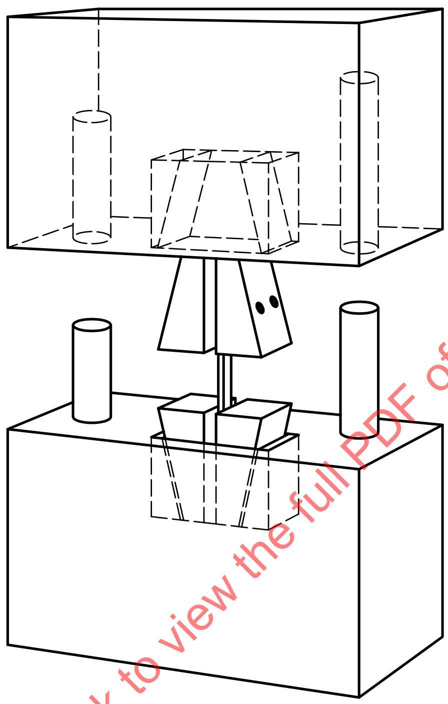
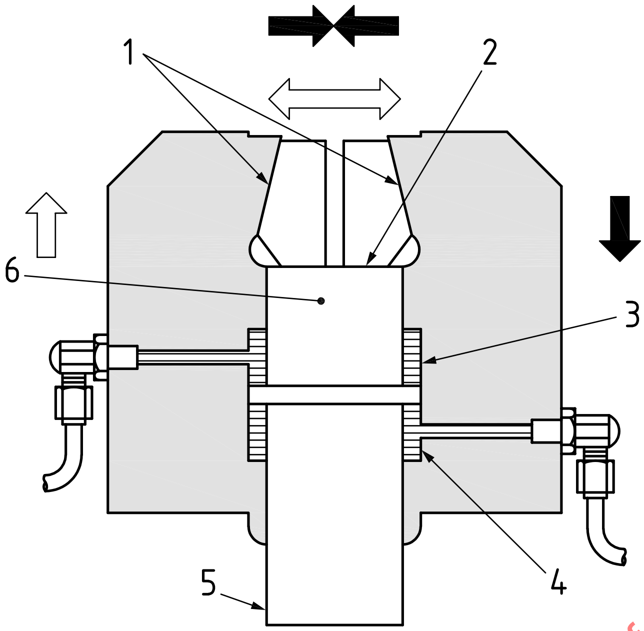


Figure C.1 — ASTM D 3410/B[2]



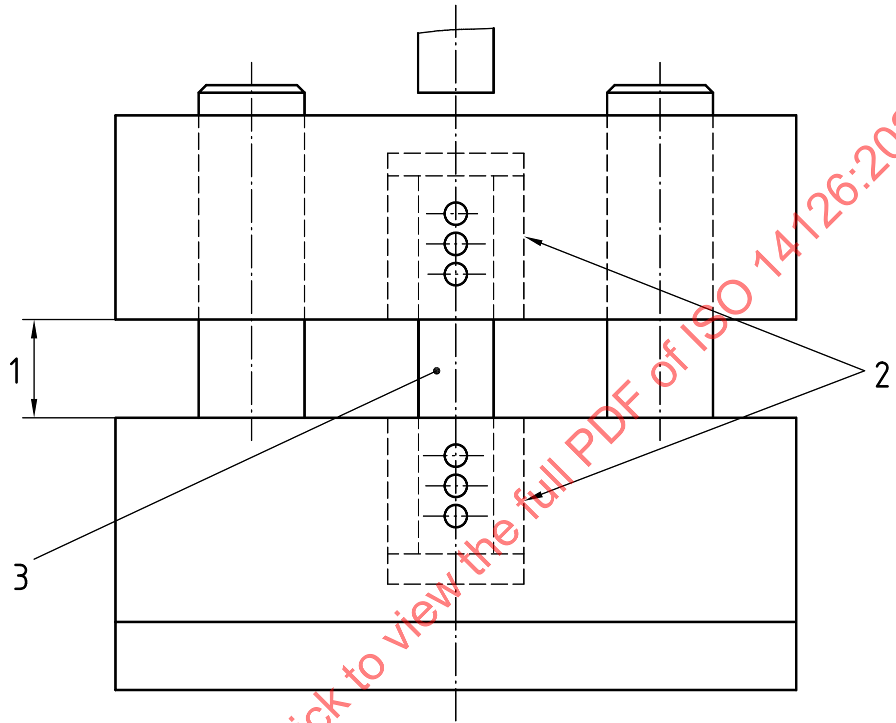
Key

1 jaw face wedge angles
2 piston rod bearing surfaces
3 open chamber
4 close chamber
5 load frame attachment point
6 grip piston

Figure C.2 — Hydraulic grips

Annex D
(informative)

Compression fixtures for method 2



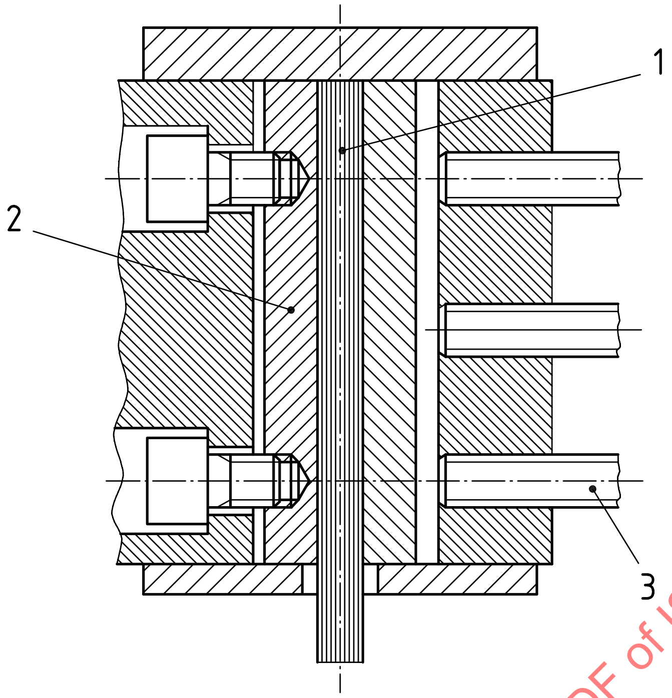
Key

1 specimen test length

2 housings for specimen ends

3 specimen

Figure D.1 — Schematic of combined loading fixture



Key

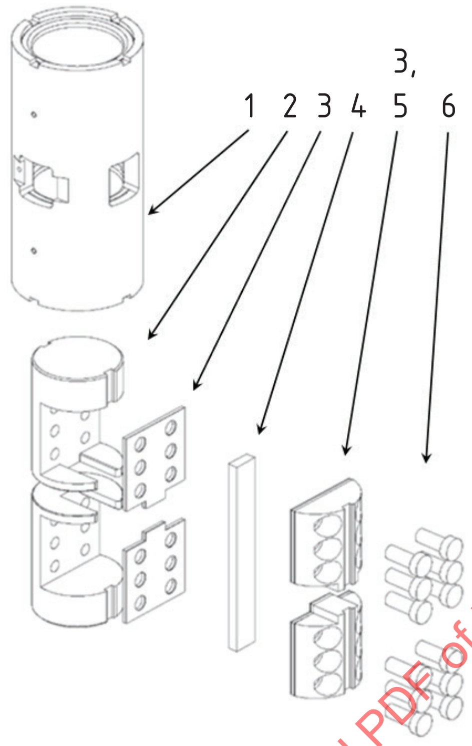
1 specimen

2 wedge

3 locking screw

Figure D.2 — Combined loading fixture details

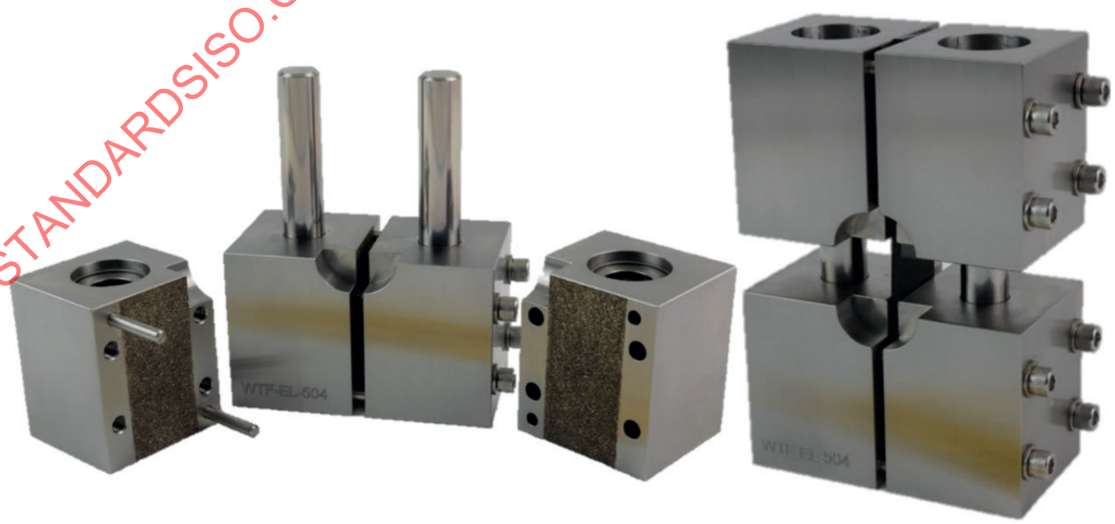
Figure D.3 — Combined loading fixture in a compression die-set



Key

1 sleeve
2 supports
3 spacers
4 specimen
5 retainers
6 bolts

Figure D.4 — JIS K 7018: 2019[8] — Combined loading fixture



NOTE Image source: Wyoming Test Fixtures Inc.

Figure D.5 — ASTM D6641[19] — Combined loading fixture

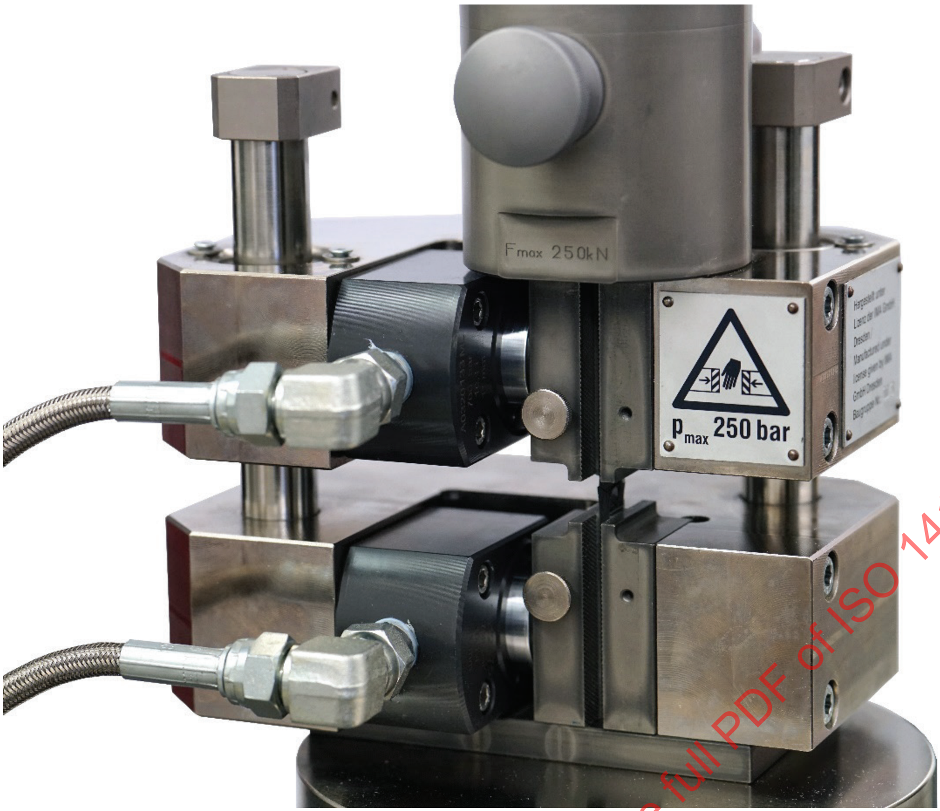


Figure D.6 — Hydraulic composites compression fixture (HCCF)