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Fibre-reinforced plastic composites — Determination of open-hole compression strength

Composites plastiques renforcés de fibres — Détermination de la résistance à la compression avec trou nu

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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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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

The document was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 13, *Composites and reinforcement fibres*.

This second edition cancels and replaces the first edition (ISO 12817:2013), which has been technically revised.

The main changes are as follows:

— the measurement of the roundness of the hole has been added;

— the dimensions of the test specimens for method 2 has been corrected;

— the preliminary loading has been modified;

— the loading procedure has been added;

— the failure mode has been refined, and the figure of typical failure modes has been changed;

— the roundness of the hole in the test reports has 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

In preparing this document, reference has been made to other similar open-hole compression methods (JIS K 7093[1], ASTM D6484/D6484M-09[2]) and related methods, i.e. open-hole tension in ASTM D5766/D5766M6[3] and pin-bearing in ISO 12815[4].

The scope covers all current and future fibre-reinforced plastic composites meeting the requirements of this document. This document incorporates three methods that have different suitability and do not necessarily yield identical properties. All the methods use the maximum load to define the open-hole compressive strength.

Fibre-reinforced plastic composites — Determination of open-hole compression strength

1 Scope

This document specifies the test method to determine the open-hole compressive strength of laminated fibre-reinforced plastic composites. The laminate is intended to be a balanced and symmetrical lay-up or be otherwise homogeneous through the thickness. This document applies to all textile diameter fibre types (carbon, glass, aramids, etc.) and matrices (e.g. thermoset, thermoplastic) that meet the requirements of this document.

This document includes three methods:

— method 1 (short specimen with support fixture);

— method 2 (short specimen without support fixture);

— method 3 (long specimen with support fixture as in ASTM D6484/D6484M-09, methods A and B).

Method 1 employs an L-shaped base fixture and two end fixtures. These end fixtures are compressed between the platens of the test machine.

Method 2 employs end supports similar to the fixtures given in ISO 14126:2023, D.1. This method is useful for cyclic loading conditions test, including under fully or partly reversed loading conditions when the specimen is clamped by hydraulic grips without support fixtures

Method 3 has two types of loading methods, i.e. 3A and 3B. In method 3A, the specimen is placed within a stabilization fixture, which is then clamped by hydraulic grips. In method 3B, the specimen is placed within a stabilization fixture and then end-loaded by platens. Full details of test methods 3A and 3B are given in ASTM D6484/D6484M-09, procedure A and procedure B, respectively.

NOTE Specimen configurations and force introduction varies for the three methods covered within this document. Results obtained using methods 1, 2 and 3 might not be equivalent for all laminates in all environments.

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 472, *Plastics — Vocabulary*

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

ISO 2818, *Plastics — Preparation of test specimens by machining*

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 472 and the following 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
open-hole diameter
diameter of the open hole in the centre of the test specimen

Note 1 to entry: Open-hole diameter is expressed in millimetres (mm).

Note 2 to entry: See Figure 1.

3.2
width
w
overall width of the specimen

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

3.3
open-hole compressive stress
value obtained by dividing a compressive load applied to a test specimen by the gross cross-section based on the overall width and thickness of the test specimen

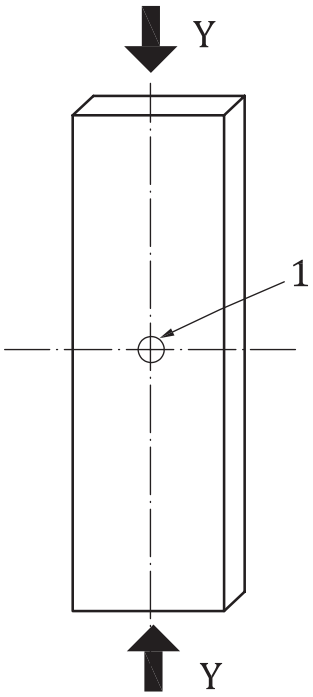
Note 1 to entry: Open-hole compressive stress is expressed in megapascals (MPa).

3.4
open-hole compressive strength
maximum *open-hole compressive stress* (3.3) generated in the test specimen

Note 1 to entry: Open-hole compressive strength is expressed in megapascals (MPa).

4 Principle

A test specimen consisting of a strip of rectangular cross-section with a plain open hole centrally positioned, as shown in Figure 1, is loaded in compression. The maximum load sustained by the specimen is used to determine the open-hole (notched) compressive strength based on the gross specimen cross-section.



Key

Y load direction

1 open hole

Figure 1 — Open-hole laminated composite test specimen and load direction

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 8.4).

5.1.3 Indication of load, the error for the indicated load not exceeding 1 %.

5.1.4 Load measurement system, comprising a mechanism to indicate continuously the compressive load applied to the test piece. The loading mechanism shall not cause delay due to inertia at the specified test speed and shall indicate the load value with a precision equal to or higher than ±1 % of the full scale of load cell measurement capacity.

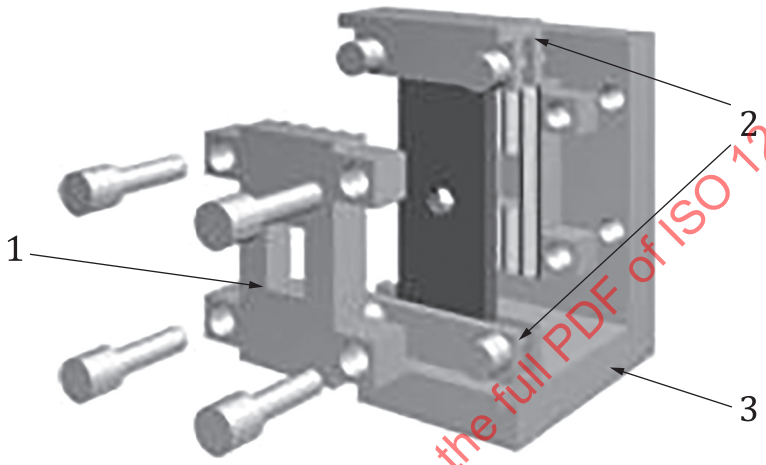
5.1.5 Loading platens (method 1 and method 3B), each (platen plate) being located on the movable part (platen plate) and fixed part (base plate), respectively, of the test machine and the centre of the upper and lower pressing faces coinciding with the centreline of the loading direction of the test machine. The alignment of the test fixture shall enable a compressive load to be applied to the platen plate and the base plate in the axial direction of a test specimen, and forces other than the compressive load shall be minimized.

5.1.6 Hydraulic grips (method 2 and method 3A), each located on the movable and fixed parts, respectively, of the test machine and the centre of the upper and lower grips coinciding with the centreline of the load gauge. The test set-up arrangement shall be such that a compressive load is applied to the upper

and lower grips in the axial direction of a test specimen, and forces other than the compressive load shall be minimized.

5.2 Test fixtures, for method 1 and method 3, which support the test specimen to prevent buckling phenomenon, and which apply compressive load to the test specimen. They shall be made of low-carbon steel or stainless steel. Figure 2 shows an outline of the out-of-plane deformation support fixture assembly for method 1. Figures 3 to 7 show detailed dimensions of the out-of-plane deformation support fixture, L-shaped base plate, end-loading fixtures and support fixture for method 1.

Method 3 requires out-of plane support fixtures. There are two compression-loading conditions for method 3, shear loaded by clamped hydraulic wedge grips (method 3A) and end loaded by platen plates (method 3B). Methods 3A and 3B require the same stabilization fixture. Details of the support fixture for method 3 are given in ASTM D6484/D6484M-09.

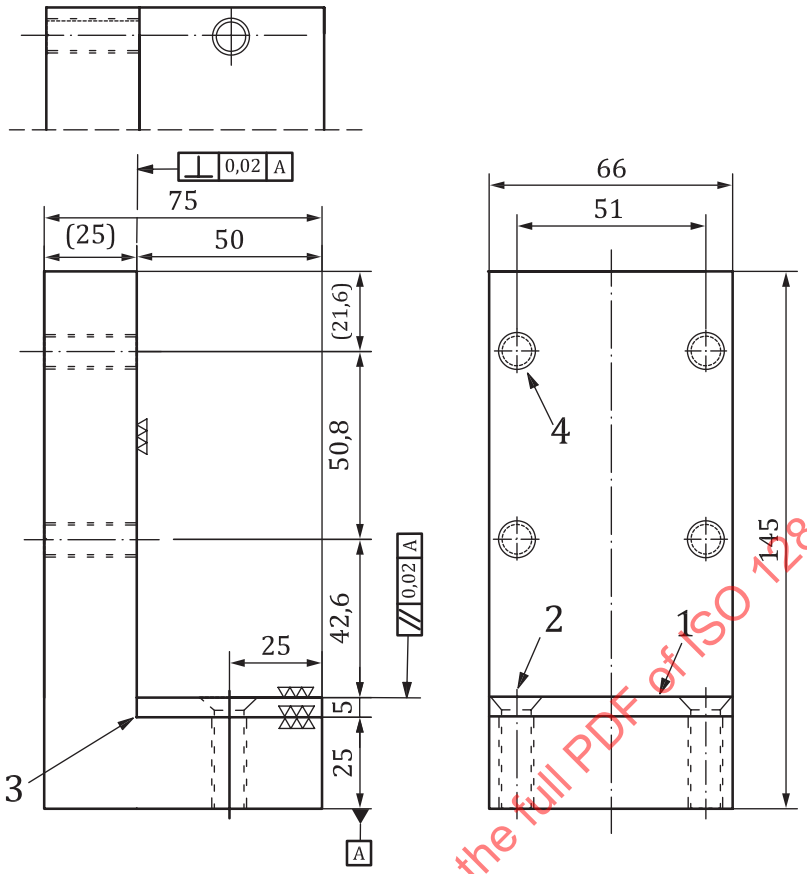


Key

1 out-of-plane deformation support fixture
2 end-loading fixtures
3 L-shaped base plate

Figure 2 — Outline of the fixture

Dimensions in millimetres

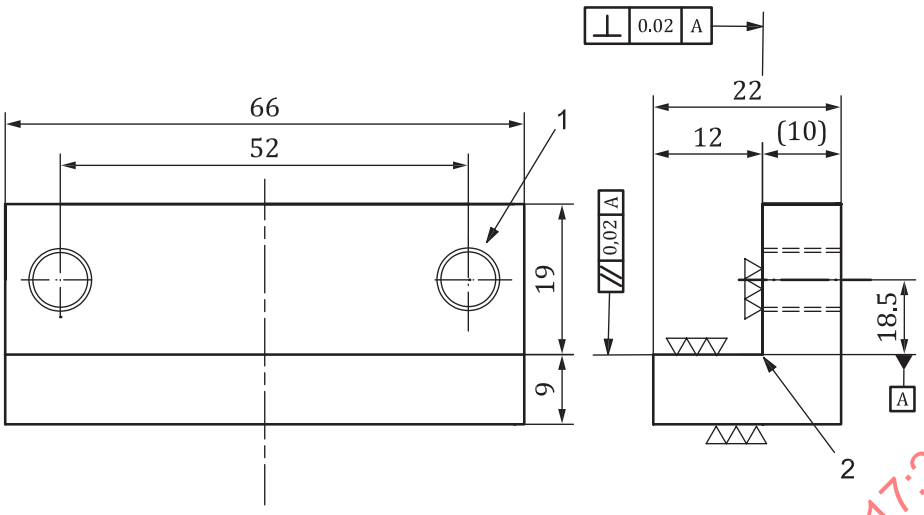


Key

1 S55C, quenched, HRC 50
2 2 × M6 countersunk screw
3 relief radius R0,1 plate R0,5
4 4 × M8 × 1,25 through

Figure 3 — L-shaped base plate for method 1

Dimensions in millimetres



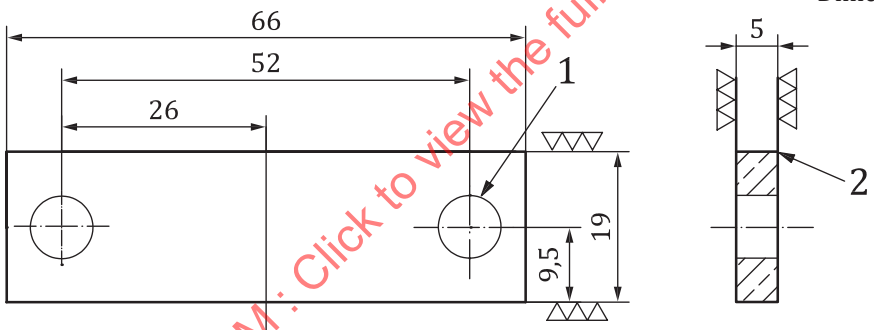
Key

1 2 × M8 × 1,25

2 relief radius R0,1 maximum

Figure 4 — End-loading fixture (upper) for method 1

Dimensions in millimetres



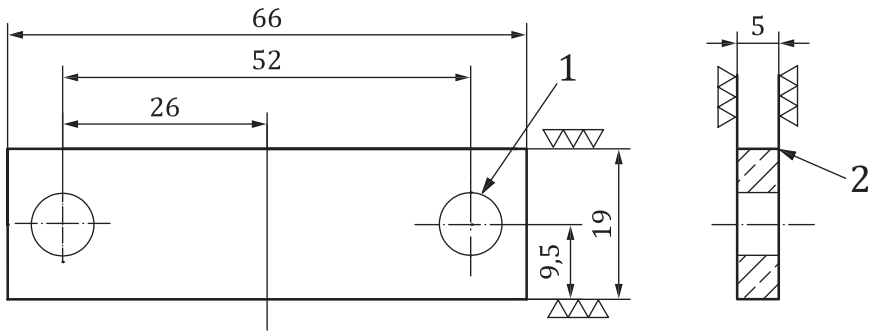
Key

1 2 × M8 × 1,25

2 relief radius R0,1 maximum

Figure 5 — End-loading fixture (lower) for method 1

Dimensions in millimetres



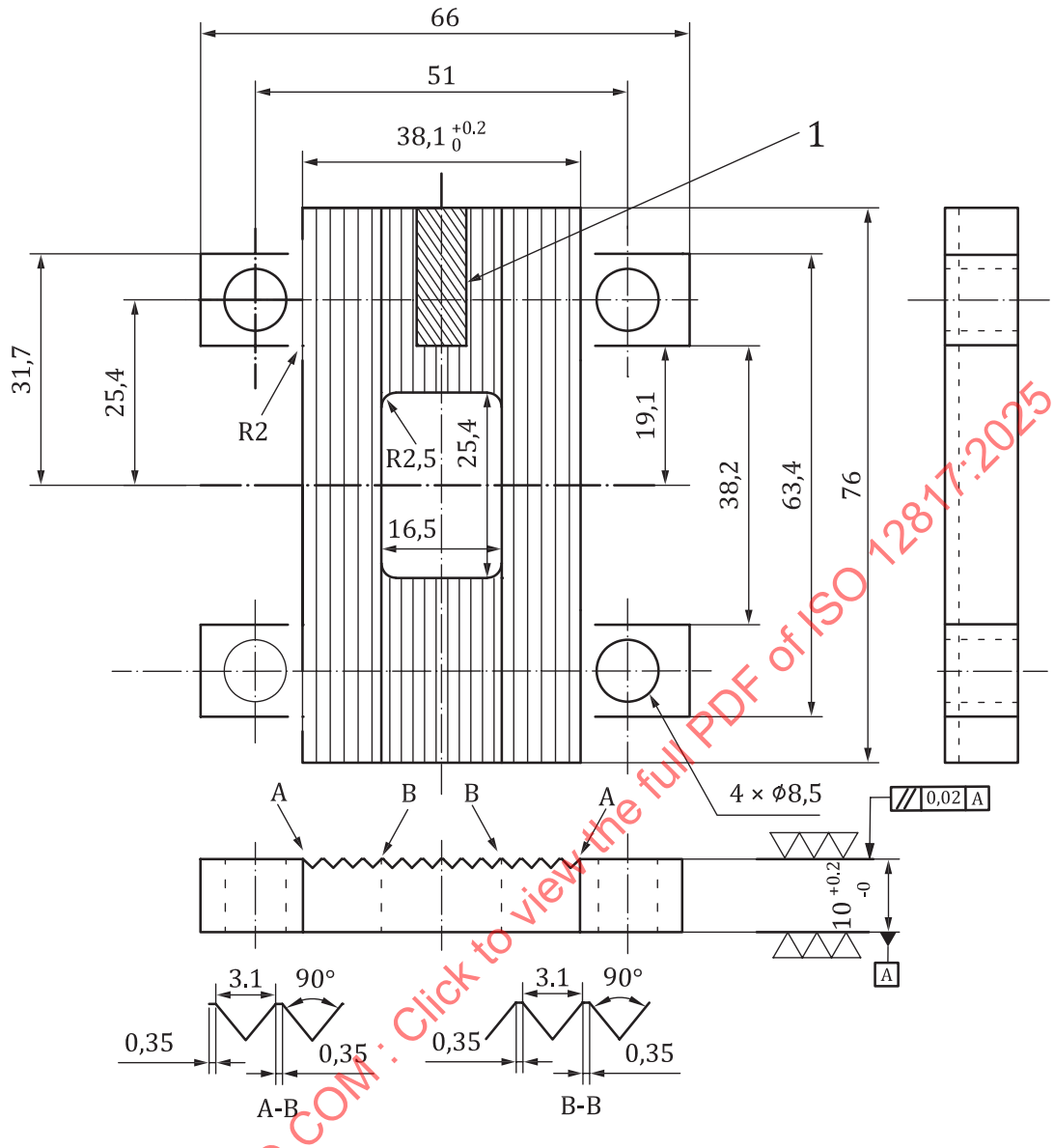
Key

1 2 × M8 × 1,25

2 relief radius R0,1 maximum

Figure 6 — End-loading fixture plate for method 1 (quantity: 2, common for the upper and lower)

Dimensions in millimetres



Key

1 strain gauge bonding area (strain gauge shall be located on the specimen) (6,8 × 18,9 mm, machined to grooved bottom surface)

A-B magnified view of section

B-B magnified view of section

Figure 7 — Out-of-plane support fixture for method 1 (quantity: two sets)

5.3 Micrometers and calipers

a) **Vernier caliper**, used to measure the length and width of the test specimen, and having a precision of 0,05 mm or better.

b) **Micrometer or equivalent**, used to measure the specimen thickness and open-hole diameter of a test specimen, and having a precision of 0,01 mm or better. The micrometer shall have faces appropriate to the surface being measured (i.e. flat faces for flat, polished surfaces and hemispherical faces for irregular surfaces).

6 Test specimens

6.1 Shape and dimensions

The major dimensions of these test specimens are shown as specified in Table 1, and are shown in Figures 8 and 9. Details of the test specimen for method 3 are given in ASTM D6484/D6484M-09.

Table 1 — Dimensions of test specimens for methods 1, 2 and 3

Dimensions in millimetres

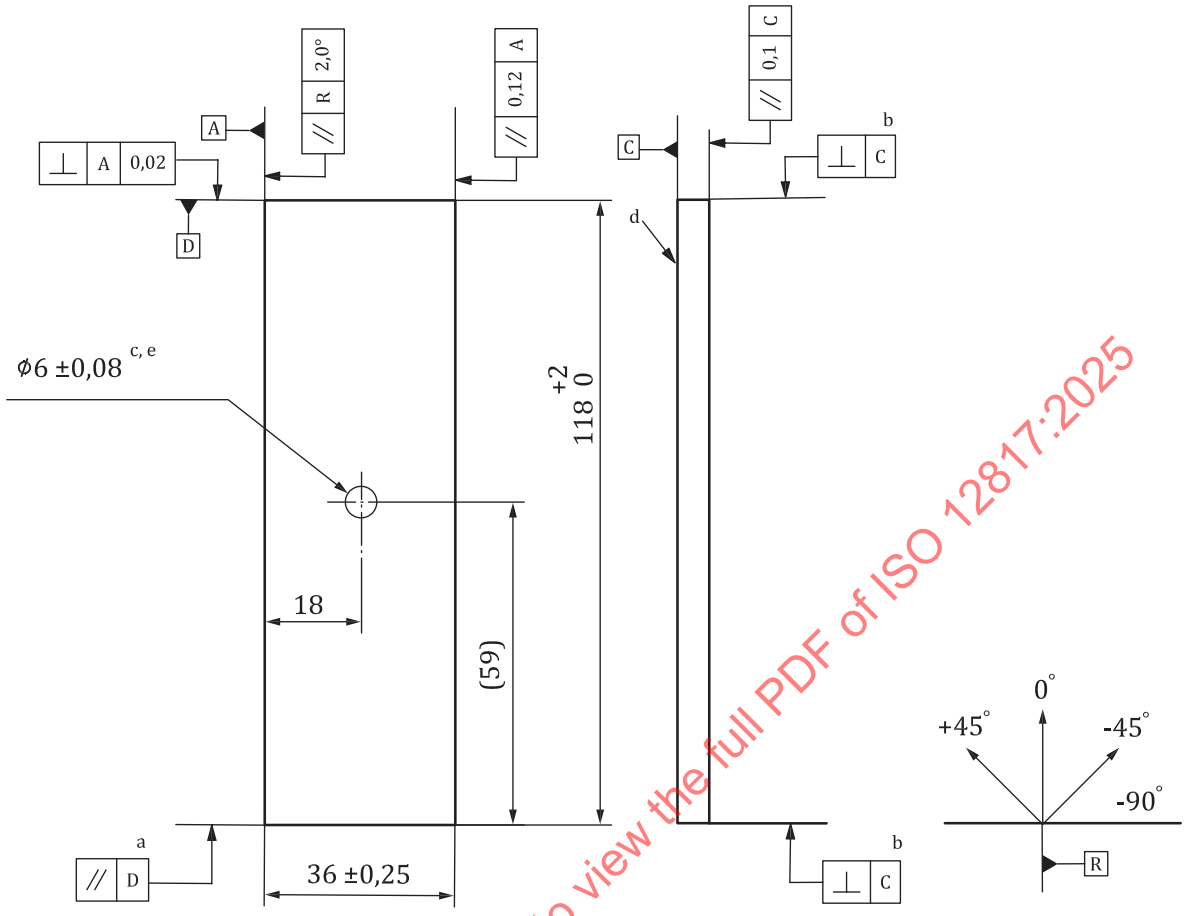
Item	Method 1	Method 2	Method 3[a]
Width *b*	36,0 ± 0,25	36,0 ± 0,5	36
Length *l*	118,0 + 2,0/-0	125,0 ± 1,0	300
Thickness *h*	2,5 (std.)	4,0 (min.)	4
Open-hole diameter *d*	6,0 ± 0,08	6,0 ± 0,02	6
[a] Mean values only; see ASTM D6484/D6484M for tolerances.			

6.2 Alternative specimen

Alternative specimens shall maintain a specimen width-to-hole diameter ratio of 6.

NOTE A 0,25“ (6,35 mm) hole in a 1,5” (38,1 mm) wide specimen meets this requirement.

Dimensions in millimetres



a Parallelism of top and bottom surfaces shall be within 0,02 mm for method 1.

b Perpendicularity of top and bottom surfaces against plane C shall be within 0,02 mm for method 1.

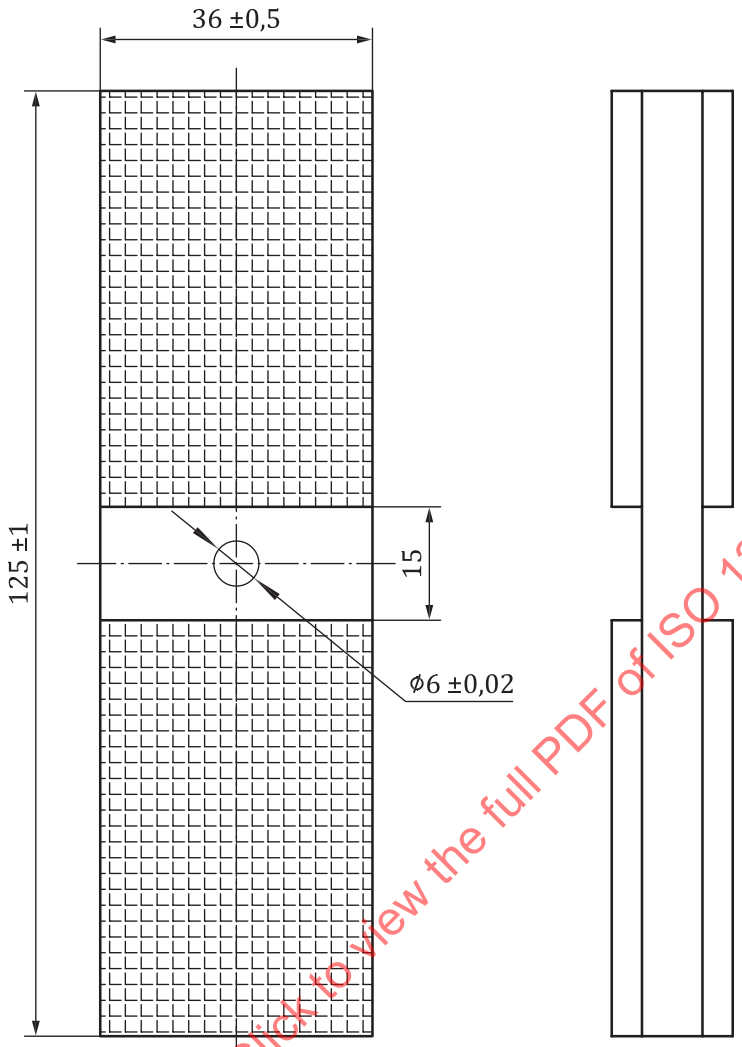
c Hole shall be free of ply peeling or other damage.

d Seal side.

e Hole to be centred by length to within 0,12 mm and by width to within 0,05 mm.

Figure 8 — Shape and dimensions of the test specimen for method 1

Dimensions in millimetres



Note End tabs are not normally required. Guidance on tabbing materials and method, if required, is given in ISO 527-4.

Figure 9 — Shape and dimensions of the test specimen for method 2

6.3 Preparation of test plates and specimens

In accordance with the ISO 1268 series or by mutual agreement of the parties concerned, the test specimens shall be machined to the specified dimensions from a laminated fibre-reinforced plastics manufactured by compression moulding, autoclave moulding or other similar methods. The typical configuration of the test specimens lamination of unidirectional material shall be quasi-isotropic laminates in 16 layers of $(45/0/-45/90)_{2S}$. When using two-dimensionally woven material, such as plain woven or satin woven fabric, $[(45/-45), (0/90)]_{ns}$ shall be employed and the integer "n" that is closest to the thickness given in Table 1 shall be determined. The edges of test specimens shall be prepared by machining in accordance with ISO 2818. The hole shall be made using a drill suitable for use with fibre-reinforced plastics, followed by reamer finishing, if required. These operations shall be properly performed to prevent the generation of burrs or interlaminar resin cracking.

6.4 Inspection of test specimens

Each test specimen shall be flat, free from any twist, and have no defect on its surface and edges. No delamination around the open-hole edges shall be allowed. The thickness and width of each test specimen shall be in accordance within the tolerance and parallelism given in Table 1.

6.5 Number of test specimens

At least five test specimens shall be tested. The number of measurements may be more than five if greater precision of the mean value is required.

7 Conditioning

Conditioning of the test specimen shall be selected in accordance with those specified in ISO 291.

8 Procedure

8.1 Test atmosphere

The specimen shall be tested as specified in ISO 291.

8.2 Measurement of dimensions of the test specimens

Prior to testing, the dimensions of test specimens shall be measured in the test conditions prescribed in Clause 5. The length of a test specimen is measured to a precision of 0,05 mm using a sliding caliper. The width and thickness in the middle area to a precision of 0,01 mm using a micrometer. The hole diameter is also measured to a precision of 0,01 mm using a micrometer.

8.3 Mounting of the test specimens

8.3.1 Method 1

As shown in Figure 2, the end-loading fixtures (see Figures 4, 5, and 6) are attached at the upper and lower ends of the test specimen by four bolts. The test specimen with the out-of-plane support fixtures (see Figure 7) is clamped and installed on the L-shaped base plate that is tighten by torque approximately 0,10 Nm to 0,15 Nm. The assembly of test specimen and fixtures are clamped between the platen plate and base plate of the test machine.

8.3.2 Method 2

The test specimen is clamped by hydraulic or equivalent grip at the upper and lower ends of the test specimen.

8.3.3 Method 3

Test specimen installation of method 3A and method 3B is given in ASTM D6484/D6484M-09, procedures A and B.

8.4 Test speed

The test speed shall be 0,5 mm/min to 1,5 mm/min for method 1 and method 2.

NOTE The test speed of method 3 is given in ASTM D6484/D6484M-09.

8.5 Preliminary loading

To stabilize the loading fixture set-up, apply a preliminary loading of 5 % of the maximum load of the specimens as the preliminary loading, and then, remove the load before conducting the compression strength test for method 1 and method 3. This preliminary loading process is not required for method 2.

Details of preliminary loading for method 3 are given in ASTM D6484/D6484M-09.

8.6 Loading

Apply the load to the specimen at a specified speed until the maximum load is reached and the load returns to 70 % of the maximum load.

8.7 Recording

Record the load applied to the test specimen and the crosshead travel (displacement) until test specimen failure.

8.8 Failure mode

Check and record the failure mode. Failures that do not occur at the hole are not acceptable failure modes and the data shall be noted as invalid. Three-place failure mode descriptors, summarized in Table 2, shall be used. This notation uses the first place to describe failure type, the second to describe failure area, and the last to describe failure location. Failure mode codes for valid tests for this document are limited to *GM, where the second and third placeholders are “Gage Middle”. The first placeholder would normally be either L for lateral, A for angled, or M for multimode. Figure 10 illustrates these three acceptable failure modes.

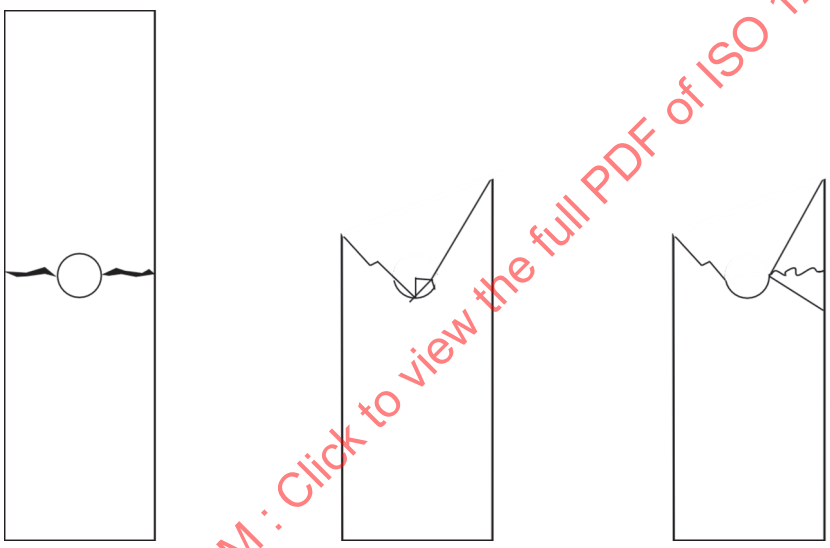


Figure 10 — Typical failure modes of open-hole compressive specimen

Table 2 — Codes of the failure modes

First character		Second character		Third character	
Failure type	**Code**	**Failure area**	**Code**	**Failure location**	**Code**
Lateral	L	Gage	G	Middle	M
Angled edge de-lamination	A				
Multimode	M				