
**Plastics — Determination of tensile
properties —**

Part 5:

**Test conditions for unidirectional fibre-
reinforced plastic composites**

Plastiques — Détermination des propriétés en traction —

*Partie 5: Conditions d'essai pour les composites plastiques renforcés de
fibres unidirectionnelles*



Reference number
ISO 527-5:2009(E)

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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.

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The main task of technical committees is to prepare International Standards. 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.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 527-5 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 527-5:1997), of which it constitutes a minor revision. The main changes are as follows:

- the normative references have been updated;
- in 6.1.2, a thickness has been specified specifically for specimens from filament-wound test plates.

ISO 527 consists of the following parts, under the general title *Plastics — Determination of tensile properties*:

- *Part 1: General principles*
- *Part 2: Test conditions for moulding and extrusion plastics*
- *Part 3: Test conditions for films and sheets*
- *Part 4: Test conditions for isotropic and orthotropic fibre-reinforced plastic composites*
- *Part 5: Test conditions for unidirectional fibre-reinforced plastic composites*

Plastics — Determination of tensile properties —

Part 5: Test conditions for unidirectional fibre-reinforced plastic composites

1 Scope

1.1 This part of ISO 527 specifies the test conditions for the determination of the tensile properties of unidirectional fibre-reinforced plastic composites, based upon the general principles given in Part 1.

1.2 See ISO 527-1:1993, Subclause 1.2.

1.3 The test method is suitable for all polymer matrix systems reinforced with unidirectional fibres and which meet the requirements, including failure mode, set out in this part of ISO 527.

The method is suitable for composites with either thermoplastic or thermosetting matrices, including preimpregnated materials (prepregs). The reinforcements covered include carbon fibres, glass fibres, aramid fibres and other similar fibres. The reinforcement geometries covered include unidirectional (i.e. completely aligned) fibres and rovings and unidirectional fabrics and tapes.

The method is not normally suitable for multidirectional materials composed of several unidirectional layers at different angles (see ISO 527-4).

1.4 The method is performed using one of two different types of test specimen, depending on the direction of the applied stress relative to the fibre direction (see Clause 6).

1.5 See ISO 527-1:1993, Subclause 1.5.

2 Normative references

The following referenced documents are indispensable for the application 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 527-1:1993, *Plastics — Determination of tensile properties — Part 1: General principles*

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

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

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

ISO 3534-1, *Statistics — Vocabulary and symbols — Part 1: General statistical terms and terms used in probability*

3 Principle

See ISO 527-1:1993, Clause 3.

4 Terms and definitions

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

4.1 gauge length

See ISO 527-1:1993, Subclause 4.1.

4.2 speed of testing

See ISO 527-1:1993, Subclause 4.2.

4.3 tensile stress σ (engineering)

See ISO 527-1:1993, Subclause 4.3, except that σ for type A specimens is defined as σ_1 and for type B specimens as σ_2 (see Clause 6 for details of type A and B specimens).

4.3.1 tensile strength σ_M

See ISO 527-1:1993, Subclause 4.3.3, except that σ_M for type A specimens is defined as σ_{M1} and for type B specimens as σ_{M2} .

4.4 tensile strain ε

increase in length per unit length of the original gauge length

NOTE 1 For type A specimens, ε is defined as ε_1 and for type B specimens as ε_2 .

NOTE 2 It is expressed as a dimensionless ratio or in percent.

4.5 tensile strain at tensile strength tensile failure strain ε_M

tensile strain at the point corresponding to the tensile strength of the specimen

NOTE 1 For type A specimens, ε_M is defined as ε_{M1} and for type B specimens as ε_{M2} .

NOTE 2 It is expressed as a dimensionless ratio or in percent.

4.6 modulus of elasticity in tension Young's modulus

E

See ISO 527-1:1993, Subclause 4.6, except that E for type A specimens is defined as E_1 and for type B specimens as E_2 .

NOTE The strain values used are as given in ISO 527-1:1993, Subclause 4.6, i.e. $\varepsilon' = 0,000\ 5$ and $\varepsilon'' = 0,002\ 5$ (see Figure 1), unless alternative values are given in the material or technical specifications.

4.7 Poisson's ratio

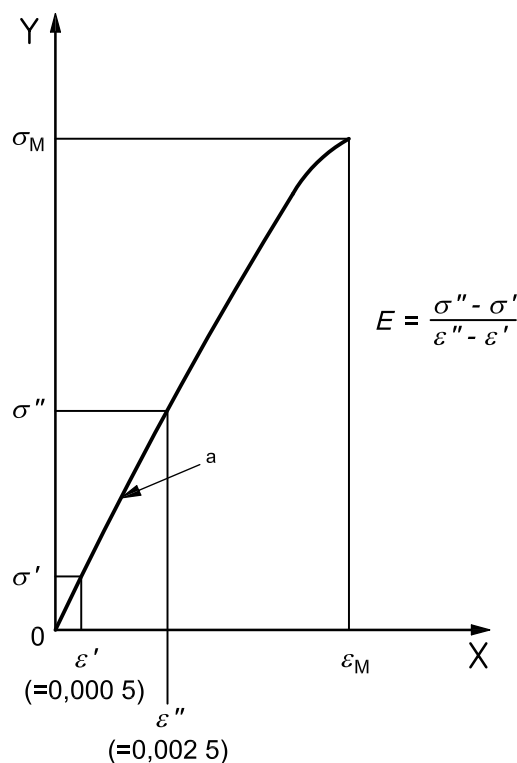
μ

See ISO 527-1:1993, Subclause 4.7, except that for type A specimens μ_b is defined as μ_{12} and μ_h as μ_{13} , using the coordinates shown in Figure 2, and for type B specimens μ_b is defined as μ_{21} and μ_h as μ_{23} .

4.8 specimen coordinate axes

coordinate axes for the material under test, as shown in Figure 2, the direction parallel to the fibres being defined as the "1"-direction and the direction perpendicular to them (in the plane of the fibres) as the "2"-direction

NOTE The "1"-direction is also referred to as the 0° or longitudinal direction and the "2"-direction as the 90° or transverse direction.



Key

X strain, ε
Y stress, σ

a Slope E .

Figure 1 — Stress-strain curve

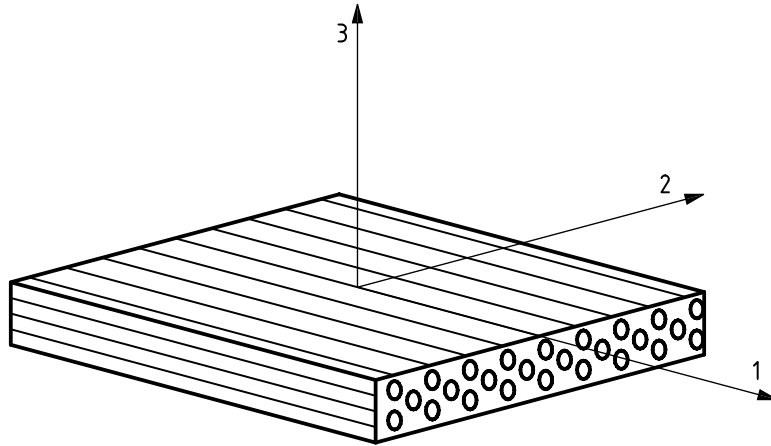


Figure 2 — Unidirectionally reinforced plastic composite showing axes of symmetry

5 Apparatus

See ISO 527-1:1993, Clause 5, except for the following:

The micrometer or its equivalent (see 5.2.1) shall read to 0,01 mm or better. It shall have a suitable-size ball-ended anvil if used on irregular surfaces and a flat anvil if used on flat, smooth (e.g. machined) surfaces.

Subclause 5.2.2 does not apply.

Care shall be exercised to ensure that the pressure exerted by the grips (see 5.1.3) is only sufficient to prevent the specimen slipping in the grip when loaded to failure. Excessive grip pressure may cause crushing of the specimen due to the low transverse strength of these materials. Hydraulic grips which can be set at a constant grip pressure are preferred.

If strain gauges bonded to the specimen are used, the errors produced by the transverse effect on the transverse gauge will generally be much larger for anisotropic composites than for metals, which are isotropic. Accurate measurement of Poisson's ratio requires correction for this effect.

NOTE It is recommended that alignment of the specimen and loading train be checked as described in Annex B.

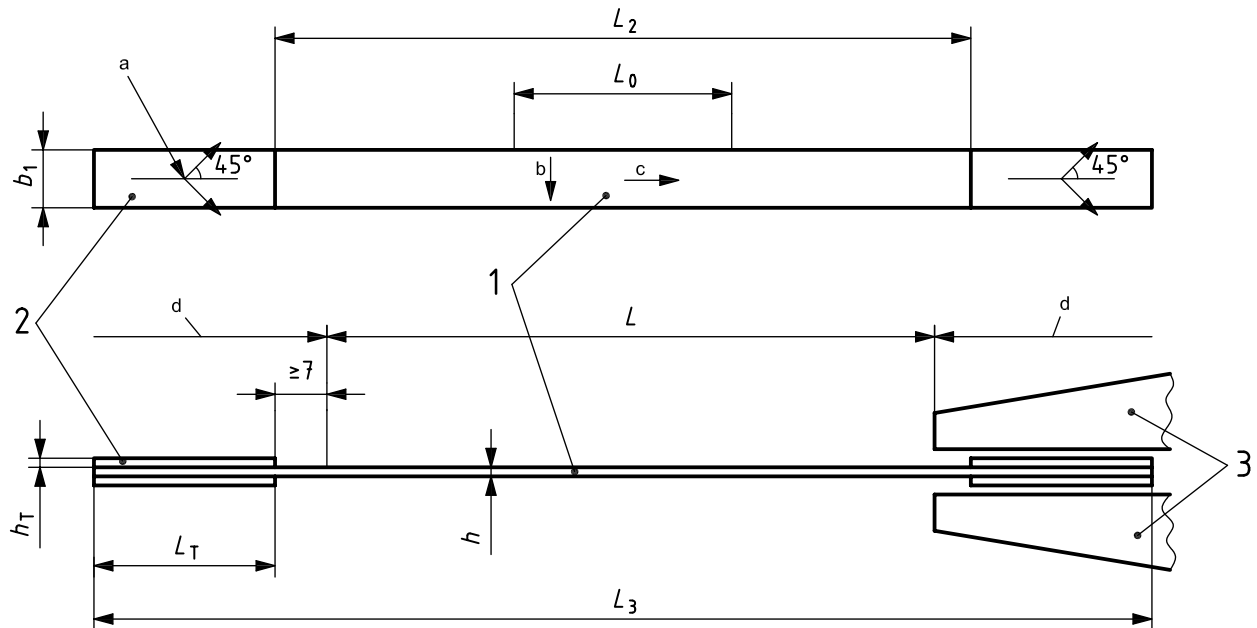
6 Test specimens

6.1 Shape and dimensions

6.1.1 General

Two types of test specimen are specified for use with this part of ISO 527, depending on the direction of test relative to the fibre direction, as detailed and illustrated in Figure 3.

Dimensions in millimetres



Key

- 1 specimen
- 2 tab
- 3 jaws
- a Tab-fibre orientation.
- b Fibre direction in type B specimen.
- c Fibre direction in type A specimen.
- d Zone covered by jaws.

Dimensions in millimetres

		Type A	Type B
L_3	Overall length	250	250 (see Note 2)
L_2	Distance between end tabs	150 ± 1	150 ± 1
b_1	Width	$15 \pm 0,5$	$25 \pm 0,5$
h	Thickness	$1 \pm 0,2$	$2 \pm 0,2$
L_0	Gauge length (recommended for extensometers)	50 ± 1	50 ± 1
L	Initial distance between grips (nominal)	136	136
L_T	Length of end tabs	> 50	> 50 (see Note 2)
h_T	Thickness of end tabs	0,5 to 2	0,5 to 2

NOTE 1 Requirements on specimen quality and parallelism are given in Clause 6.

NOTE 2 For specimens taken from filament-wound plates prepared using ISO 1268-5, an overall specimen length of 200 mm is acceptable, with an end-tab length of 25 mm.

Figure 3 — Type A and type B specimens

6.1.2 Type A specimen (for longitudinal direction)

Type A specimens shall have a width of $15 \text{ mm} \pm 0,5 \text{ mm}$, an overall length of 250 mm and a thickness of $1 \text{ mm} \pm 0,2 \text{ mm}$ or, for specimens from filament-wound test plates, a thickness of $2 \text{ mm} \pm 0,2 \text{ mm}$. The sides of each individual specimen shall be parallel to within 0,2 mm.

6.1.3 Type B specimen (for transverse direction)

Type B specimens shall have a width of $25 \text{ mm} \pm 0,5 \text{ mm}$, an overall length of 250 mm and a thickness of $2 \text{ mm} \pm 0,2 \text{ mm}$. The sides of each individual specimen shall be parallel to within 0,2 mm.

For type B specimens taken from filament-wound plates prepared using ISO 1268-5, a test specimen length of 200 mm is acceptable.

6.2 Preparation of specimens

6.2.1 General

In the case of moulding and lamination materials, prepare a test plate in accordance with the relevant part of ISO 1268 or another specified/agreed procedure. Cut individual specimens, or groups of specimens (see Annex A), from the test plate.

In the case of finished products (for example, for quality control during manufacture or on delivery), take specimens from flat areas.

Take all specimens with their axis within $0,5^\circ$ of the mean fibre axis.

Parameters for machining specimens are specified in ISO 2818. Further guidance on cutting out specimens is given in Annex A.

6.2.2 End tabs

The ends of the specimen shall be reinforced with end tabs, preferably made of cross-ply or fabric glass-fibre/resin laminate with the fibres at $\pm 45^\circ$ 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).

Alternative tabbing arrangements are permissible, but shall be shown, before use, to give at least equal strength and no greater coefficient of variation (see ISO 527-1:1993, Subclause 10.5, and ISO 3534-1) than the recommended tabs. Possible alternatives include tabs made from the material under test, mechanically fastened tabs, unbonded tabs made of rough materials (such as emery paper or sandpaper, and the use of roughened grip faces).

If the test is carried out on untabbed specimens, the distance between the grips shall be the same as that between the tabs of tabbed specimens.

6.2.3 Application of end tabs

Bond the end tabs to the specimen with a high-stretch adhesive as described in Annex A.

NOTE The same procedure can be used for individual specimens and for a group of specimens.

6.3 Gauge marks

See ISO 527-1:1993, Subclause 6.3.

6.4 Checking the specimens

See ISO 527-1:1993, Subclause 6.4.

7 Number of specimens

See ISO 527-1:1993, Subclauses 7.1 and 7.3 (Subclause 7.2 does not apply).

8 Conditioning

See ISO 527-1:1993, Clause 8.

9 Procedure

9.1 Test atmosphere

See ISO 527-1:1993, Subclause 9.1.

9.2 Measurement of specimen dimensions

See ISO 527-1:1993, Subclause 9.2, except that the thickness shall be measured to the nearest 0,01 mm and Notes 3 and 4 do not apply.

9.3 Clamping

See ISO 527-1:1993, Subclause 9.3. Insert the end tabs so that they are ≥ 7 mm inside the grip as shown in Figure 3.

9.4 Prestresses

See ISO 527-1:1993, Subclause 9.4.

9.5 Setting of extensometers and strain gauges and placing of gauge marks

See ISO 527-1:1993, Subclause 9.5. Measure the gauge length to an accuracy of 1 % or better.

9.6 Test speed

The test speed for type A specimens shall be 2 mm/min and for type B specimens 1 mm/min.

9.7 Recording of data

See ISO 527-1:1993, Subclause 9.7.

10 Calculation and expression of results

See ISO 527-1:1993, Clause 10, except that the definitions given in Clause 4 of this part of ISO 527 apply and strain values shall be reported to three significant figures.

11 Precision

The precision of this test method is not known because interlaboratory data are not yet available.

12 Test report

The test report shall include the following information:

- a) a reference to this part of ISO 527, including the type of specimen and the test speed, written in the following format:

Tensile test	ISO 527-5 / A / 2
Type of specimen _____	
Test speed in millimetres per minute _____	

- b) to q) see ISO 527-1:1993, Clause 12, b) to q), including fibre type, fibre content and fibre geometry (e.g. unidirectional tape) in 12 b).

.....

Annex A (normative)

Specimen preparation

A.1 Machining the specimens

In all cases, take the following precautions:

- Avoid working under conditions that would create 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.

A.2 Preparation of specimens with bonded end tabs

A recommended method is as follows:

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

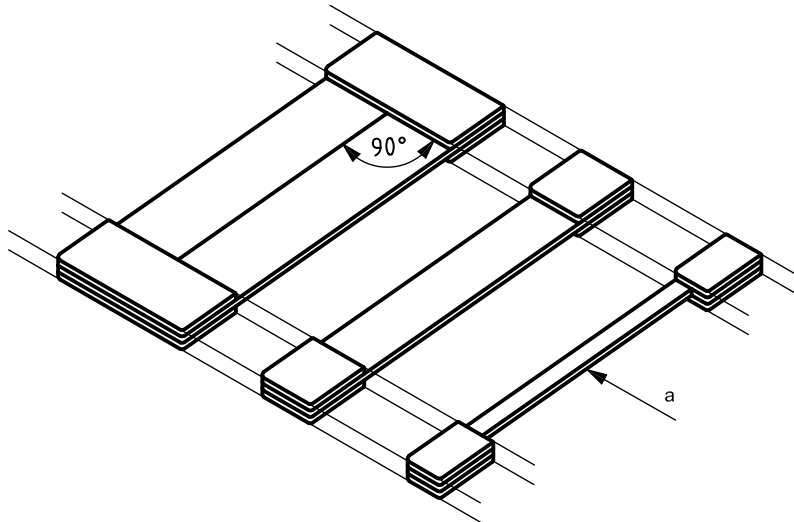
The mean fibre axis can be determined by splitting the edge of the test panel and examining the fibres, repeating the operation every few specimens to confirm the direction. If splitting does not give a clean edge due to misalignment between plies or layers, the panel shall not be used unless it represents a particular product or the result of a particular process.

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 blast with suitable sand 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 A.1, using a high-stretch adhesive and strictly following the adhesive manufacturer's instructions.

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 be 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 recommended by the adhesive manufacturer for the time recommended by the manufacturer.
- e) Cut the sheet, together with the strips constituting the end tabs, into test specimens (see Figure A.1).



a Trimmed to waste.

Figure A.1 — Tabbed panel for specimen preparation

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Annex B (informative)

Alignment of specimens

It is recommended that the alignment of the tensile-testing machine and the test specimen be checked at the centre of the gauge length using a strain-gauged coupon of the same material as is to be tested. Use a device or procedure which ensures that specimens are positioned in the grips in a repeatable manner. Strain-gauge the coupon as shown in Figure B.1, attaching two gauges (SG1, SG2) to one face of the coupon, approximately one-eighth of the specimen width from the edge and midway between the tabs, and attaching a third gauge (SG3) on the centreline of the opposite face, also midway between the tabs.

Compare the output of the gauges at the mid-point of the strain range used to measure Young's modulus, i.e. at 0,001 5 for the strain values given in 4.6. Using Equations (B.1) and (B.2), calculate the bending strain, expressed as a percentage, in the width (B_b) and thickness (B_h) directions, respectively.

$$B_b = \frac{4|\varepsilon_2 - \varepsilon_1|}{3\varepsilon_{av}} \times 100 \quad (\text{B.1})$$

$$B_h = \frac{|\varepsilon_{av} - \varepsilon_3|}{\varepsilon_{av}} \times 100 \quad (\text{B.2})$$

where

ε_1 , ε_2 and ε_3 are the strains recorded by strain gauges SG1, SG2 and SG3, respectively;

$$\varepsilon_{av} = \left(\frac{\varepsilon_1}{4} + \frac{\varepsilon_2}{4} + \frac{\varepsilon_3}{2} \right)$$

Finally, ensure that the bending strains satisfy the condition given in Inequality (B.3):

$$B_b + B_h < 3,0 \% \quad (\text{B.3})$$

NOTE 1 The use of further strain gauges next to the grips is necessary to fully check all sources of misalignment.

NOTE 2 The alignment of individual specimens can be checked in the width direction using a clip-on extensometer with a longitudinal-strain output for each edge of the specimen.

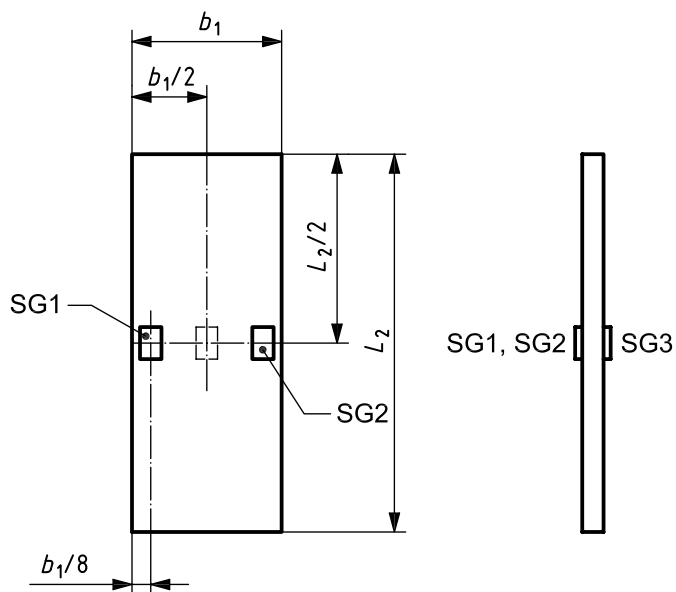


Figure B.1 — Strain-gauge locations (SG1, SG2 and SG3) for system alignment check

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