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## Plastics — Determination of tensile properties

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Part 4: Test conditions for isotropic and orthotropic  
fibre-reinforced plastic composites

## National foreword

This British Standard is the UK implementation of EN ISO 527-4:2023. It is identical to ISO 527-4:2023. It supersedes BS EN ISO 527-4:2021, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee PRI/42, Fibre reinforced thermosetting plastics and preregs.

A list of organizations represented on this committee can be obtained on request to its committee manager.

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EUROPÄISCHES KOMITEE FÜR NORMUNG

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

## European foreword

This document (EN ISO 527-4:2023) has been prepared by Technical Committee ISO/TC 61 "Plastics" in collaboration with Technical Committee CEN/TC 249 "Plastics" the secretariat of which is held by SIS.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by October 2023, and conflicting national standards shall be withdrawn at the latest by October 2023.

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

This document supersedes EN ISO 527-4:2021.

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## Endorsement notice

The text of ISO 527-4:2023 has been approved by CEN as EN ISO 527-4:2023 without any modification.

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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.

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 documents 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](http://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](http://www.iso.org/iso/foreword.html).

This document was prepared by 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 third edition cancels and replaces the second edition (ISO 527-4:2021), of which it constitutes a minor revision.

The main changes are as follows:

- symbols [Figures 1](#) and [5](#) have been updated to match the text;
- symbols in [Table B.2](#) have been updated for consistency (upper case to lower case);
- symbols in [Annex E](#) have been updated for consistency (upper case to lower case);
- a reference has been added to the bibliography.

A list of all parts in the ISO 527 series can be found on the ISO website.

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](http://www.iso.org/members.html).

## Introduction

This document introduces a new test specimen, type 4, with a tapered geometry for use without end tabs. The geometry has been developed to overcome difficulties with bonding end tabbed test specimens, especially when testing materials based on a thermoplastic matrix.

Guidance on gripping, including grip face design, is also added.

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# Plastics — Determination of tensile properties —

Part 4:

## Test conditions for isotropic and orthotropic fibre-reinforced plastic composites

### 1 Scope

This document specifies the test conditions for the determination of the tensile properties of isotropic and orthotropic fibre-reinforced plastic composites, based upon the general principles given in ISO 527-1.

NOTE 1 Unidirectional reinforced materials are covered by ISO 527-5.

The methods are used to investigate the tensile behaviour of the test specimens and for determining the tensile strength, tensile modulus, Poisson's ratios and other aspects of the tensile stress-strain relationship under the defined conditions.

The test method is suitable for use with the following materials:

- fibre-reinforced thermosetting and thermoplastic composites incorporating non-unidirectional reinforcements such as mats, woven fabrics, woven rovings, chopped strands, combinations of such reinforcements, hybrids, rovings, short or milled fibres or prepregged materials (prepregs);

NOTE 2 Injection moulded specimens are covered by ISO 527-2.

- combinations of the above with unidirectional reinforcements and multidirectional reinforced materials constructed from unidirectional layers, provided such laminates are symmetrical;

NOTE 3 Materials with completely or mainly unidirectional reinforcements are covered by ISO 527-5.

- finished products made from materials mentioned above.

The reinforcement fibres covered include glass fibres, carbon fibres, aramid fibres and other similar fibres.

### 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 527-1:2019, *Plastics — Determination of tensile properties — Part 1: General principles*

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

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

ISO 16012, *Plastics — Determination of linear dimensions of test specimens*

### 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 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).

Note 2 to entry: The values of the gauge length that are indicated for the specimen types in the different parts of ISO 527 represent the maximum relevant gauge length.

[SOURCE: ISO 527-1:2019, 3.1]

### 3.2 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).

[SOURCE: ISO 527-1:2019, 3.2]

### 3.3 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).

[SOURCE: ISO 527-1:2019, 3.3]

### 3.4 test speed

$v$

rate of separation of the gripping jaws

Note 1 to entry: It is expressed in millimetres per minute (mm/min).

[SOURCE: ISO 527-1:2019, 3.5]

### 3.5 stress

$\sigma$

<engineering> normal force per unit area of the original cross-section within the *gauge length* (3.1)

Note 1 to entry: It is expressed in megapascals (MPa).

Note 2 to entry: In order to differentiate from the true stress related to the actual cross-section of the specimen, this stress is frequently called "engineering stress".

Note 3 to entry:  $\sigma$  for "1"-direction specimens is defined as  $\sigma_1$  and for "2"-direction specimens as  $\sigma_2$  (see 3.9 and Figure 2 for definitions of these directions).

[SOURCE: ISO 527-1:2019, 3.6, modified — Domain "<engineering>" and Note 3 to entry have been added.]

### 3.5.1 strength

$\sigma_m$   
maximum stress observed during a tensile test

Note 1 to entry: It is expressed in megapascals (MPa).

[SOURCE: ISO 527-1:2019, 3.6.2]

### 3.6 strain

$\varepsilon$   
increase in length per unit original length of the gauge

Note 1 to entry: It is expressed as a dimensionless ratio, or as a percentage (%).

[SOURCE: ISO 527-1:2019, 3.7]

#### 3.6.1 strain at strength

$\varepsilon_m$   
strain at which the *strength* (3.5.1) is reached

Note 1 to entry: It is expressed as a dimensionless ratio, or as a percentage (%).

[SOURCE: ISO 527-1:2019, 3.7.3]

### 3.7 tensile modulus modulus of elasticity under tension

$E_t$   
slope of the stress/strain curve  $\sigma(\varepsilon)$  in the interval between the two strains  $\varepsilon_1 = 0,05\%$  and  $\varepsilon_2 = 0,25\%$

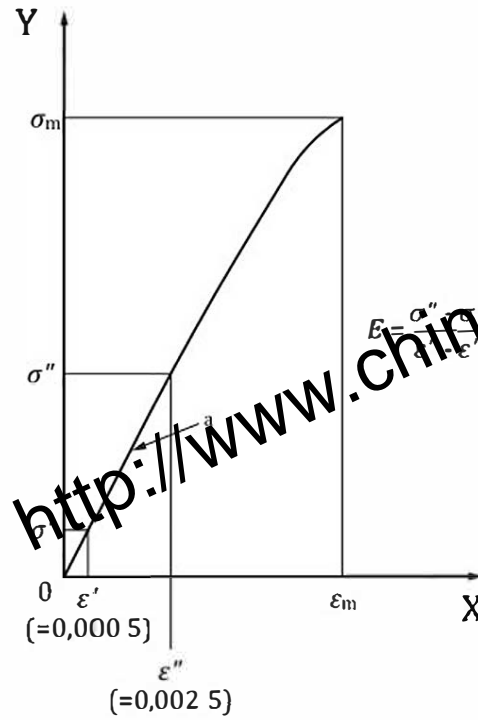
Note 1 to entry: It is expressed in megapascals (MPa).

Note 2 to entry: It may be calculated either as the chord modulus or as the slope of a linear least-squares regression line in this interval.

Note 3 to entry: This definition does not apply to films.

Note 4 to entry: See [Figure 1](#).

[SOURCE: ISO 527-1:2019, 3.9]



**Key**  
 X strain,  $\epsilon$   
 Y stress,  $\sigma$   
 a slope  $E$

**Figure 1 — Stress-strain curve**

**3.8  
 Poisson's ratio**

$\mu$   
 negative ratio of the strain change  $\Delta\epsilon_n$ , in one of the two axes normal to the direction of extension, to the corresponding strain change  $\Delta\epsilon_1$  in the direction of extension, within the linear portion of the longitudinal versus normal strain curve

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

Note 2 to entry: Since the lateral strain change  $\Delta\epsilon_n$  is a negative number and the longitudinal strain change  $\Delta\epsilon_1$  is positive, the Poissons ratio as defined in ISO 527-1:2019, 3.10 is a positive number.

[SOURCE: ISO 527-1:2019, 3.10]

**3.9  
 specimen coordinate axes  
 1, 2, 3**

axes, where "1"-direction is normally defined in terms of a feature associated with the material structure or the production process, such as the length direction in continuous-sheet processes (see [Figure 2](#)) and the "2"-direction is perpendicular to the "1"-direction.

Note 1 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. The "3"-direction is perpendicular to the plane of the "1"-direction and "2"-direction". The "3"-direction is also referred to as the "through-thickness" direction for planar systems.

Note 2 to entry: For unidirectional materials covered by part 5 of this International Standard, the direction parallel to the fibres is defined as the "1"-direction and the direction perpendicular to the fibres (in the plane of the prepreg/plate) as the "2"-direction.

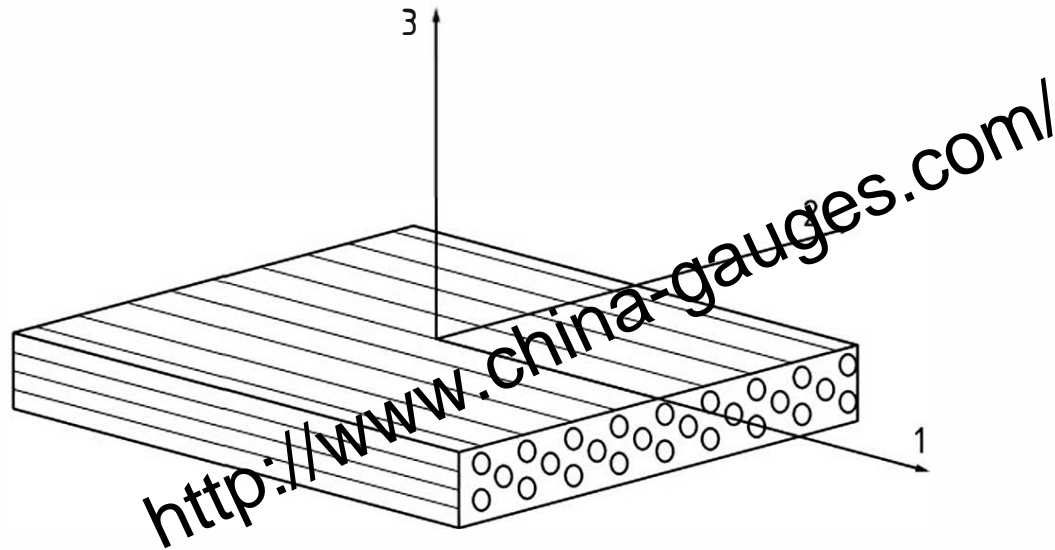


Figure 2 — Fibre-reinforced plastic composite showing axes of symmetry

### 3.10 failure position

$u_F$   
failure location of specimen type 4 within the local coordinate system ( $u, v$ ) of the tapered section

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

Note 2 to entry: See [Figure 5](#).

## 4 Principle

According to ISO 527-1.

## 5 Apparatus

The apparatus shall conform to ISO 527-1:2019, Clause 5, except for the following.

The micrometre or its equivalent (see ISO 16012:2015, 5.5) 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.

When using extensometers with specimen type 4, use a gauge length of 25 mm (see ISO 527-1:2019, 5.1.5).

It is recommended to check alignment of the specimen and loading train as described in [Annex A](#).

## 6 Test specimens

### 6.1 Shape and dimensions

Four types of test specimen are specified for use with this document, as detailed and illustrated in [Figure 3](#) (type 1 B), [Figure 4](#) (types 2 and 3) and [Figure 5](#) (type 4).

Type 1B is for testing fibre-reinforced thermoplastics. Type 1B specimens may also be used for fibre-reinforced thermosets if they break within the gauge length. Type 1B shall not be used for multidirectional, continuous-fibre-reinforced materials.

Type 2 is rectangular without end-tabs, and Type 3 is rectangular with bonded end-tabs. They are for testing fibre reinforced thermosets and thermoplastics. Specimens with unbonded end tabs are considered as type 2.

The preferred width of type 2 and type 3 specimens is 25 mm, but widths of 50 mm or greater may be used if the tensile strength is low due to the particular type of reinforcement used.

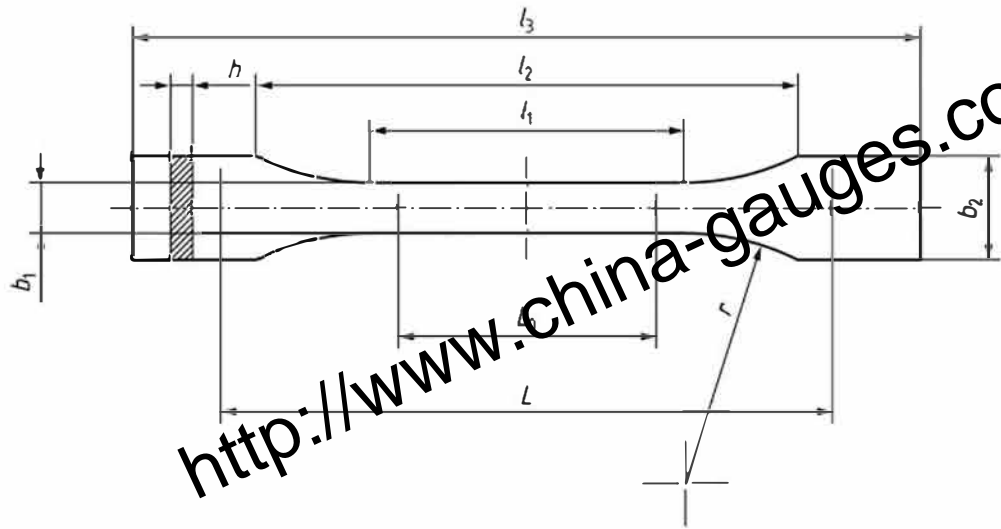
Type 4 is tapered without end-tabs and for testing fibre-reinforced composites, especially for testing multidirectional, continuous-fibre reinforced thermoplastics. Please refer to [Figure B.1](#).

The thickness of type 2, type 3 and type 4 specimens shall be between 2 mm and 10 mm.

To decide whether to use specimen with or without tabs, first carry out tests without using tabs (specimen type 2 [rectangle] or type 4 [tapered]) and if the tests are not successful, i.e. if almost all specimens break in the grips (see [Clause 10](#)), perform test with bonded end tabs on the specimens (specimen type 3). Refer to [Annex C](#) for guidance on unbonded tabs or gripping condition without tabs using fine grip faces and careful control of the gripping force.

NOTE Continuous fibre reinforced composites typically have high fracture forces due to high tensile strength of their fibres. Using specimen thicknesses larger than 4 mm can require an increased clamping length to counter high clamping pressures.

The recommended specimen thickness for continuous-fibre-reinforced composites is 2 mm. For compression-moulded materials, the thickness between the end-pieces of any type of specimen shall at no point deviate from the mean by more than 2 %.

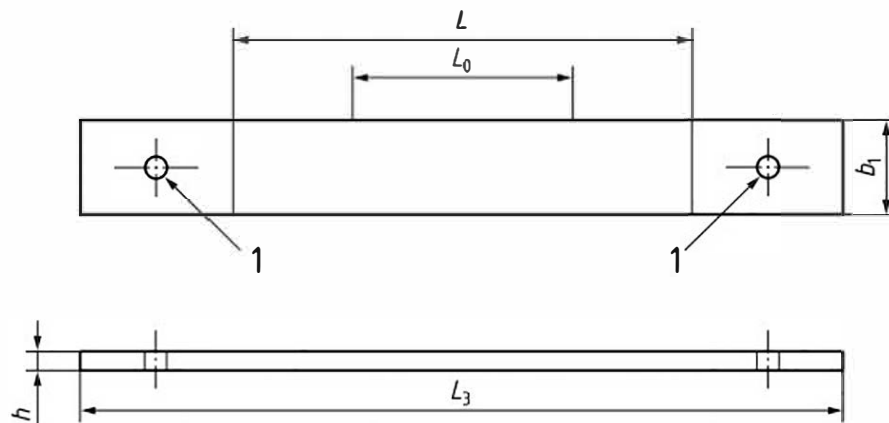


Symbol	Name	Dimensions in millimetres
$l_3$	Overall length <sup>a</sup>	$\geq 150$
$l_1$	Length of narrow parallel-sided portion	$60,0 \pm 0,5$
$r$	Radius <sup>b</sup>	$\geq 60$
$b_2$	Width at ends	$20,0 \pm 0,2$
$b_1$	Width of narrow portion	$10,0 \pm 0,2$
$h$	Thickness	2 to 10
$L_0$	Gauge length (recommended for extensometers)	$50,0 \pm 0,5$
$L$	Initial distance between grips	$115 \pm 1$

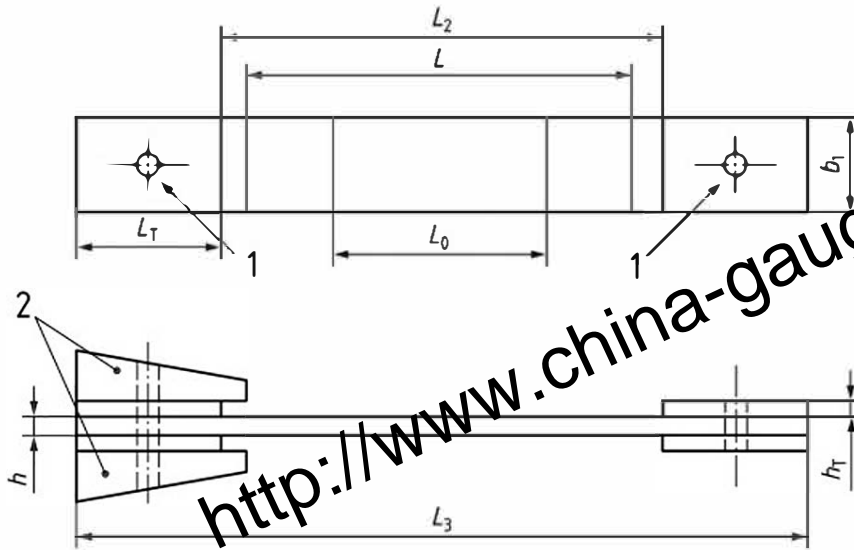
<sup>a</sup> For some materials, the length of the tabs can be extended (e.g. so that  $l_3 = 200$  mm) to prevent breakage or slippage of the specimen in the jaws.

<sup>b</sup> It should be noted that a thickness of 4 mm gives a specimen which is identical to the type 1B specimen specified in ISO 527-2.

Figure 3 — Type 1B specimen



a) Type 2 specimen



b) Type 3 specimen

**Key**

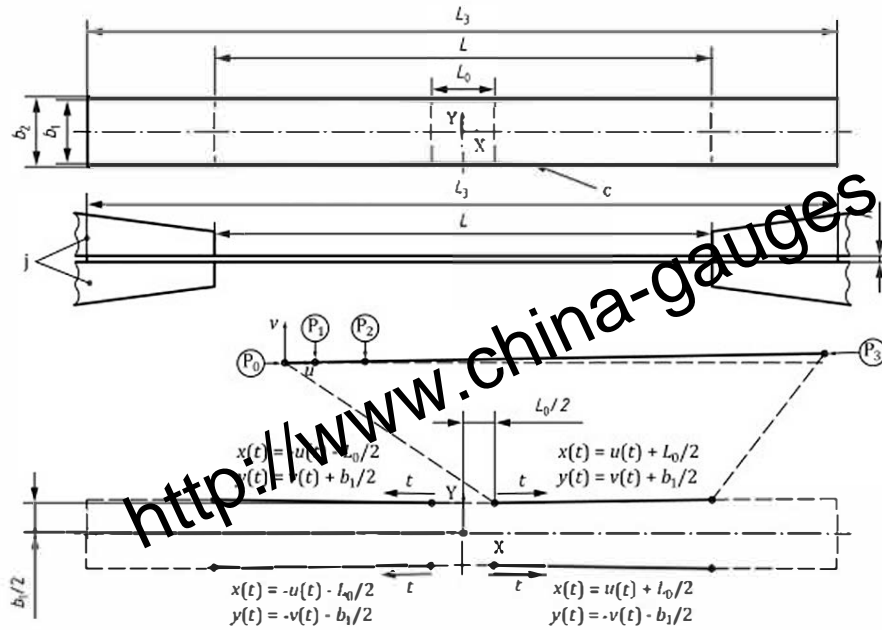
- 1 centring holes (optional),  $\phi D$
- 2 jaws

Symbol	Name	Dimensions in millimetres	
		Type 2	Type 3
$L_3$	Overall length	$\geq 250$	$\geq 250$
$L_2$	Distance between end tabs	—	$150 \pm 1$
$b_1$	Width	$25 \pm 0,5$ or $50 \pm 0,5$	$25 \pm 0,5$ or $50 \pm 0,5$
$h$	Thickness	2 to 10	2 to 10
$L_0$	Gauge length (recommended for extensometers)	$50 \pm 1$	$50 \pm 1$
$L$	Initial distance between grips (nominal)	$150 \pm 1$	$150 \pm 1$
$l_T$	Length of end tabs	—	$\geq 50$
$h_T$	Thickness of end tabs	—	1 to 3
$D$	Diameter of centring holes	$3 \pm 0,25$	$3 \pm 0,25$

NOTE Requirements on specimen quality and parallelism are given in ISO 527-1:2019, 6.4.

**Figure 4 — Type 2 and type 3 specimens**





Symbol	Name	Dimensions in millimetres
		<b>Type 4</b>
$L_3$	Total length	$\geq 300$
$b_1$	Width of parallel mid-section	$25 \pm 0,5$
$b_2$	Width at ends	$28 \pm 0,5$
$H$	Thickness	2 to 10
$L_0$	Gauge length (recommended for extensometers)	$25 \pm 1$
$L$	Initial distance in between grips (nominal)	200
$P_0$	Bézier curve control point in $(u, v)$ coordinates	(0; 0)
$P_1$	Bézier curve control point in $(u, v)$ coordinates	(4,86; 0)
$P_2$	Bézier curve control point in $(u, v)$ coordinates	(13,0; 0)
$P_3$	Bézier curve control point in $(u, v)$ coordinates	(87,5; 1,5)
$c$	Edge is a Bézier curve	
$j$	Clamping jaws	

NOTE Requirements on specimen quality and parallelism are given in ISO 527-1:2019, 6.4.

Figure 5 — Type 4 specimen

[Formulae \(1\)](#) and [\(2\)](#) are the Bézier curve specifically resolved for the specimen type 4 to calculate a polyline being applicable on most CNC machines. They define the local coordinates  $(u, v)$  of the tapered section's edge depicted in [Figure 5](#). The transformation into the specimens coordinate system  $(x, y)$  is depicted in [Figure 5](#). The variable  $t$  should not exceed increments higher than 0,05 to avoid a coarse partitioned polyline. A more detailed description on how to construct the type 4 specimen is given in [B.2](#).

$$u(t) = 63,08t^3 + 9,84t^2 + 14,58t \quad (1)$$

$$v(t) = 1,5t^3 \quad (2)$$

with  $t \in [0,1]$  with  $\Delta t \leq 0,05$

## 6.2 Preparation of specimens

### 6.2.1 General

In the case of moulding and lamination materials, prepare a panel in accordance with ISO 1268 (all parts) or another specified/agreed procedure. Cut individual specimens, or groups of specimens in the case of type 3 specimens (see [Annex D](#)), from the panel.

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

Parameters for machining specimens shall be as specified in ISO 2818. Further guidance on cutting specimens is given in [Annex D](#).

For machining of type 4 specimens only, a polyline of the required profile can be calculated using the [Formulae \(1\)](#) and [\(2\)](#).

### 6.2.2 End tabs for type 3 specimens

The ends of the specimen shall be reinforced, preferably with end tabs 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 1 mm and 3 mm, with a tab angle of  $90^\circ$  (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 527-1:2019, 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 fine grip faces without tabs as described in [Annex C](#).

### 6.2.3 Applications of end tabs for type 3 specimens

Bond the end tabs to the specimen with a high-stretch adhesive in accordance with [Annex D](#).

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

## 6.3 Gauge marks

The gauge marks shall conform to ISO 527-1:2019, 6.3.

Mark the parallel mid-section of the specimen when using specimen type 4. The first mark indicates the centre of the parallel mid-section. Two additional marks shall be placed in a distance of 12,5 mm from the centre (see [Figure 6](#)). The marks indicate the width and thickness measurement points of the specimen. In addition, the outer marks indicate the extensometer placement positions.

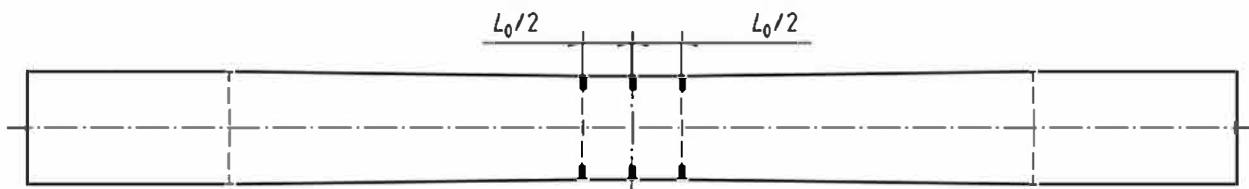


Figure 6 — Positions of supporting marks

## 6.4 Checking the specimens

The specimen checking shall conform to ISO 527-1:2019, 6.4.

## 6.5 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 [3.10](#)).

## 7 Number of specimens

The number of specimens shall conform to ISO 527-1:2019, Clause 7, except the following.

Specimens that slip or break inside the grips or at the grips edge regions are invalid. Those specimens shall be discarded and further specimens shall be tested.

## 8 Conditioning

Conditioning shall be in accordance with ISO 527-1:2019, Clause 8.

## 9 Procedure

### 9.1 Test atmosphere

Test atmosphere shall be in accordance with ISO 527-1:2019, 9.1.

### 9.2 Measurement of specimen dimensions

The measurement shall conform to ISO 527-1:2019, 9.2, except for the following.

For specimen type 4, record the width, thickness and total length in accordance with ISO 16012. The width and thickness shall be measured at the specimen's centre and within a distance of 12,5 mm from the centre equally on both sides (see positions of gauge marks defined in [6.3](#)). The total length shall be measured to the nearest 0,5 mm for a failure location related tensile strength estimation (see ISO 527-1:2019, 10.1). Use the mean values of measured width and thickness to calculate the cross-section of the test specimen's measurement area.

### 9.3 Clamping

The clamping shall conform to ISO 527-1:2019, 9.3.

NOTE 1 Invalid failure (see [Clause 7](#)) of the test specimen inside the grip or at the grips edge regions can often be avoided by adjusting the gripping force or pressure (e.g. via torque or manometer depending on gripping system used) so that it does not cause fracture or crushing of the test specimen. Misalignment of specimen can also be a reason for the invalid failure described.

NOTE 2 For testing with specimen without tabs (type 2 and 4) invalid failure can be caused by crushing or significant damage of the fibres in the outer layers of the specimen, which can be avoided by a low gripping surface roughness in the range of emery paper (e.g. P400 according ISO 6344-1).

### 9.4 Prestresses

The prestress shall conform to ISO 527-1:2019, 9.4.

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

The strain measurement setting shall conform to ISO 527-1:2019, 9.5. Measure the gauge length to an accuracy of 1 % or better.

## 9.6 Speed of testing

### 9.6.1 For type 1B test specimens

- a) 10 mm/min for routine quality control;
- b) 2 mm/min for qualification tests:
  - when measuring the maximum elongation,
  - when determining the tensile modulus of elasticity.

### 9.6.2 For type 2, type 3 and type 4 test specimens

- a) 5 mm/min for routine quality control;
- b) 2 mm/min for qualification tests:
  - when measuring the maximum elongation,
  - when determining the tensile modulus of elasticity.

## 9.7 Recording of data

The recording of data shall conform to ISO 527-1:2019, 9.7.

## 10 Calculation and expression of results

### 10.1 Calculation of all properties for parallel sided specimens

The property calculation shall conform to ISO 527-1:2019, Clause 10, except that the definitions given in [Clause 3](#) apply and strain values shall be reported to three significant figures.

If Poisson's ratio is required, calculate it at the strain values given in [3.8](#).

### 10.2 Failure location related calculation of tensile strength for type 4 specimens

The tensile strength shall be calculated based on the failure location for specimen type 4 in accordance with [Annex E](#). All other properties of type 4 specimens shall be calculated according to [10.1](#).

## 11 Precision

See [Annex B](#).

### 12 Test report

The test report shall include the following information:

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



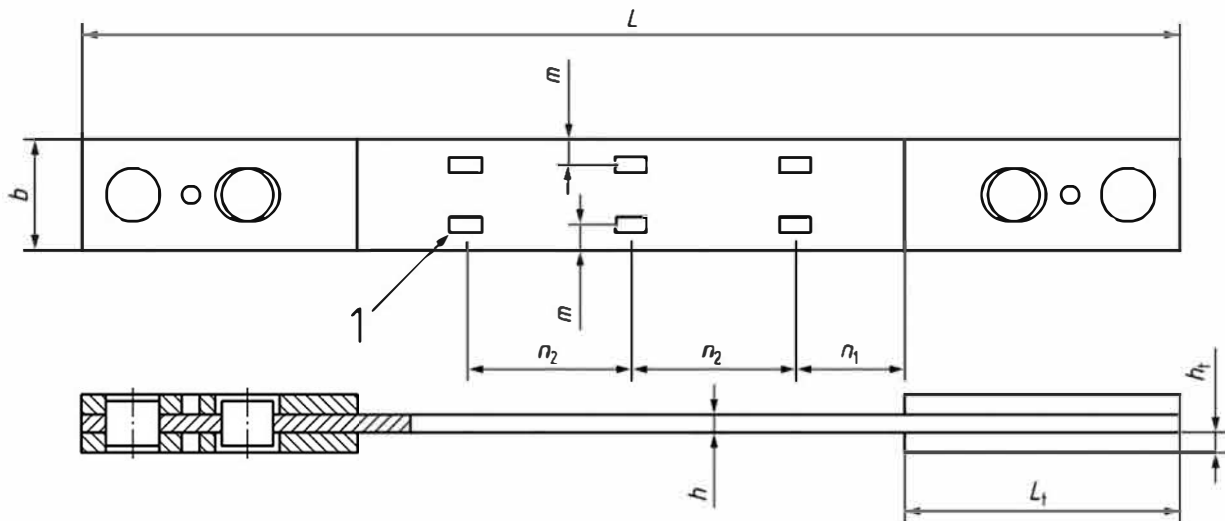
- b) to q) see ISO 527-1:2019, Clause 12, (j) to q), including fibre type, fibre content and fibre geometry (e.g. mat) in 12 b);
- r) failure mode and location of failure for each specimen.

**Annex A**  
 (informative)

**Alignment of specimens**

It is recommended that the alignment situation of the tensile-testing machine be checked in accordance with ISO 23788, or ASTM E 1012, using a thin rectangular alignment gauge, instrumented with strain gages applied at 3 planes (A, B and C) and 4 strain gages per plane.

The result of the alignment verification depends on the dimensions of the alignment gauge being used, the positions of the strain gages and their stiffness. Therefore, the alignment gauge only reflects the expected situation when testing with the 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, is considered to be acceptable.



**Key**  
 1 strain gauge

Symbol	Name	Dimensions in millimetres
$L$	Overall length	254
$h$	Height	3,2
$b$	Width	25,4
$L_t$	Tab length	64
$h_t$	Tab height	4,5
$m$	Strain gauge distance from specimen's edge in transverse direction	5
$n_1$	Strain gauge distance from tab in specimen's longitudinal direction	25
$n_2$	Distance between strain gauges in specimen's longitudinal direction	38

**Figure A.1 — Example of a standard alignment gauge equipped with 12 strain gages and exchangeable protection tabs**

In order to avoid multiple alignment verifications related to each of the specimen shapes and dimensions being used for testing, it is acceptable to verify the testing machine and its loading train by using the alignment gauge shown in [Figure A.1](#). This alignment gauge is in accordance with the Nadcap Audit Criteria AC7122-I and -R, Appendix A which is broadly used in the aerospace industry. Results for bending and percent bending obtained using this gage are higher than results obtained with alignment gauges produced in accordance with the specimen dimensions shown in this document.

Verify the alignment situation in at least two positions of the gage, normally turned by 180° around the centre axis of the alignment gauge. Optionally, measurements in top-down position of the alignment gauge can be carried out. In accordance to ASTM E 1012 and ISO 3778, it is important to:

- zero all strain gages in a free hanging position of the alignment gauge and note the remaining residual bending;
- measure bending ( $\mu\text{m}/\text{m}$ ) in clamped position at zero load or a small preload;
- measure bending ( $\mu\text{m}/\text{m}$ ) and Percent Bending (%) at 1 000 microstrains ( $\mu\text{m}/\text{m}$ ) of axial deformation. When using the standard alignment gauge, a load of approximately 16,5 kN is applied at this deformation;
- open the lower grip and measure again the bending ( $\mu\text{m}/\text{m}$ ) in a free hanging position to ensure that the alignment gauge was not altered during the measurement.

For static tensile tests, percent bending shall not exceed 8 % at an axial alignment gauge deformation of 1 000  $\mu\text{m}/\text{m}$ .

Repeat the alignment verification annually, in case of doubts and after any major modification of the testing machine that may impair the alignment situation, such as delocalization, maintenance, calibration or re-installation of grips or load cells. It is normally not required to repeat the alignment verification after a simple change of grip inserts.

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



## Annex B (informative)

### Testing with tapered tensile specimen geometry without tabs (type 4)

#### B.1 Overview

This annex describes tensile testing using the tapered tensile specimen geometry (type 4). Applying tabs is a challenging and time-consuming process especially for thermoplastic based composites. Moreover, temperature or media have a large influence on the behaviour of adhesives and the functioning of the tabs in many cases. Due to the slightly tapered geometry, no tabs and therefore no adhesives need to be applied to the specimen. This testing method is more efficient, prevents tab debonding during testing and is very robust against clamping failures.

#### B.2 Type 4 specimen's geometry

The type 4 specimen tapered section has a shape based on a cubic Bézier curve.

There are several possibilities to get the type 4 specimens shape, depending on the technical equipment accessible.

##### Method 1: Download the specimen geometry

The specimen geometry (defined with polylines) can be downloaded at <https://standards.iso.org/iso/527/-4/ed-3/en/>. If this URL is not reachable at the given time, then choose method 2 or method 3.

##### Method 2: Construct the type 4 specimen using CAD software

By using the control points  $P_0$ ,  $P_1$ ,  $P_2$  and  $P_3$  defined in [6.1](#) a Bézier curve can be constructed within CAD Software. It is recommended to partition the resulting Bézier curve into a polyline for better compatibility with other computer aided systems like CNC machines. Some CAD Software might refer to Bézier curves differently, for example, as cubic splines. The CAD software manual is the best location to check how Bézier curves can be constructed in that particular software.

##### Method 3: Calculate the polyline based on the Bézier curve

If the available technical equipment or application is not able to directly construct a Bézier curve using the control points  $P_0$ ,  $P_1$ ,  $P_2$  and  $P_3$  defined in [6.1](#), the local Bézier curve's points  $(u, v)$  can be calculated using a state of the art spreadsheet program (e.g. MS Excel, Libre Office Calc, etc.). State of the art machines and programs can handle linear polylines.

Calculate the  $u$ -coordinate using [Formula \(1\)](#) and  $v$ -coordinate using [Formula \(2\)](#). The recommended linear step of the variable  $t$  is less than or equal to 0,025 to avoid a coarse polyline.

In most cases CAD software should be able to support translation and mirroring of polylines on planes. If in rare cases such features are not available, [Figure 5](#) depicts the transformations for each of the four specimen type 4 edges of the tapered sections. These can be easily applied using state of the art spreadsheet program before importing the transformed polylines into the CAD program.

#### B.3 Comparison of type 4 and type 3 geometry

An interlaboratory test was conducted to compare type 3 and type 4 geometry results. Equivalent accuracy in test results together with much higher efficiency and robustness of the type 4 geometry in



comparison to the rectangular specimen geometry with tabs (type 3) were obtained for two different materials. The materials consisted of glass fibre fabric reinforced thermoplastics where glass fibres were aligned in two major material directions indexes as 1 and 2, from which the major direction 1 was tested.

In [Table B.2](#) the statistical properties used are:

- $s_r$  = within-laboratory standard deviation,
- $s_R$  = between-laboratory standard deviation,
- $r$  = 95 % repeatability limit =  $2,8 s_r$ ,
- $R$  = 95 % reproducibility limit =  $2,8 s_R$ .

NOTE 1 Two fabric materials described in [Table B.1](#) were tested from 5 different laboratories. Each laboratory tested 10 x type 4 specimens, generally by micro water jet cutting as well as 10 x type 3 and 10 x type 4 cut by each laboratory's in-house techniques (milling or water jet cutting). The goal was to compare the testing results of type 3 specimen with the type 4 (accuracy) and determine the influences of different measurement techniques (strain gauge, optical strain gauge, etc.), cutting procedures as well as personnel and machinery influences (robustness). The RRT results are shown in [Table B.2](#).

NOTE 2 The results showed the same accuracy of the type 4 geometry in terms of testing results in comparison to the type 3 specimens, due to the same measured modulus and tensile strength. In addition, the type 4 geometry is more robust to user created variations (i.e. thickness of bond, type of bond, bonding process, clamping of specimen, type of clamps, grip surface) For type 4 specimens: ~96 % of tested specimen showed valid failure; while for type 3: ~56 % of tested specimen showed valid failure). Moreover, type 4 geometry shows higher efficiency (lower testing effort and faster specimen preparation) than the type 3 specimen geometry.

NOTE 3 [Table B.2](#) shows tensile strength  $\sigma_{11}$  and Young's modulus  $E_{11}$  of the material direction 1. The round brackets state the percentage distribution of the glass fibres in the material direction 1 and 2.

NOTE 4 Detailed data are available in Reference [8].

**Table B.1 — Materials tested in research**

Fibre	Glass fibre (GF)	Glass fibre (GF)
Matrix	Polypropylene (PP)	Polyamide 66 (PA66)
Fibre volume fraction	47 %	47 %
Fabric	Balanced (50/50)	Unbalanced (80/20)
Thickness of plate	2 mm	2 mm
Tested specimens per laboratory	<ul style="list-style-type: none"> <li>— 10 type 3, cut by each test laboratory</li> <li>— 10 type 4, water jet cut - organiser supplied</li> <li>— 10 type 4, cut by each test laboratory</li> </ul>	<ul style="list-style-type: none"> <li>— 10 type 3, cut by each test laboratory</li> <li>— 10 type 4, water jet cut - organiser supplied</li> <li>— 10 type 4, cut by each test laboratory</li> </ul>

Table B.2 — Precision data of round robin test with 5 participating laboratories

Material	Tensile properties	Repeatability conditions		Reproducibility conditions		Mean result
		$s_r$	$r$	$s_R$	$R$	
specimen type 3						
GF/PP balanced (50/50)	$\sigma_{11}$	25,01	70,04	25,14	71,79	428,33 MPa
	$E_{11}$	0,63	1,75	0,84	2,35	19,90 GPa
GF/PA6 unbalanced (80/20)	$\sigma_{11}$	21,78	60,98	23,88	65,47	593,50 MPa
	$E_{11}$	0,62	1,74	0,91	2,55	30,21 GPa
specimen type 4						
GF/PP balanced (50/50)	$\sigma_{11}$	21,27	65,03	24,07	67,39	426,36 MPa
	$E_{11}$	0,98	2,73	1,42	3,98	20,10 GPa
GF/PA6 unbalanced (80/20)	$\sigma_{11}$	27,01	75,62	29,39	82,28	603,30 MPa
	$E_{11}$	0,73	2,05	1,27	3,54	30,42 GPa

## Annex C (informative)

### Unbonded tabs or gripping condition without tabs using fine grip face

#### C.1 Overview

This annex describes test methods (1) using unbonded tabs, or (2) without tabs using fine grip faces. For the latter case, special consideration should be given to the gripping condition. Care should be taken to ensure that damage to the material in the gripping regions is prevented when testing specimen types with unbonded tabs are used or those are tab-less. Final fracture at the edge or inside of the gripping regions, tab-debonding and damage during the tab application process are typical examples of unsatisfactory damage that may occur before and during the tests. Consideration should be given to the correct selection and use of (1) unbonded tabs made of rough materials (such as emery paper or sand paper), or (2) grip faces with fine teeth and appropriate gripping force, to avoid damage to the specimen.

#### C.2 Test specimens

See [Clause 6](#), except for the description about end tabs (see [6.2.2](#) and [6.2.3](#)). This annex permits less gripping conditions as well as alternative tabbing arrangements according to [6.2.2](#).

#### C.3 Unbonded tabs

Tests with unbonded tabs are carried out as follows.

Emery papers or sandpapers are inserted between the grip face and specimen, where rough surfaces contact specimen surfaces. Two layers of papers are recommended.

#### C.4 Gripping condition without tabs using fine grip faces

- Grip face with fine roughness is recommended for this test condition.
- Grip force should be controlled with care taken to not damage the surface of the specimen. Hydraulic gripping should be used for better control over grip force.

NOTE For thermoplastic matrix composite materials, unbonded tabs or gripping without tabs using fine grip faces give better test results for:

- tests of composite materials made of thermoplastic matrix resin which has difficulty in bonding;
- warpage in laminates are often observed for composite materials made of thermoplastic matrix. In this case, process of tab bonding brings unnecessary damage and cracks to the specimens.

### C.5 Comparison of grip conditions

Three test methods are selected which can give equal strength to that with tabs. These methods are decided based on the subtraction of the standard deviation from the average strength for tests with tabs.

- 1) Two layers of emery papers (P 400 to P 600) are inserted between the grip face and specimen.

Condition 1 in [Table C.2](#) and [Figure C.1](#).

- 2) Only one layer of emery papers (P 400 to P 600) is inserted between grip face and specimen and the grip faces have a similar morphology to that of the emery paper.

Condition 2 in [Table C.2](#) and [Figure C.1](#).

- 3) No unbonded tab is used. Grip surfaces have similar morphology to emery paper. The face saw pitch is less than 0,25 mm, and the gripping force is controlled with care not to give damage to the specimen.

Condition 3 and 4 in [Table C.2](#) and [Figure C.1](#).

NOTE Detailed data are available in References [9] to [11].

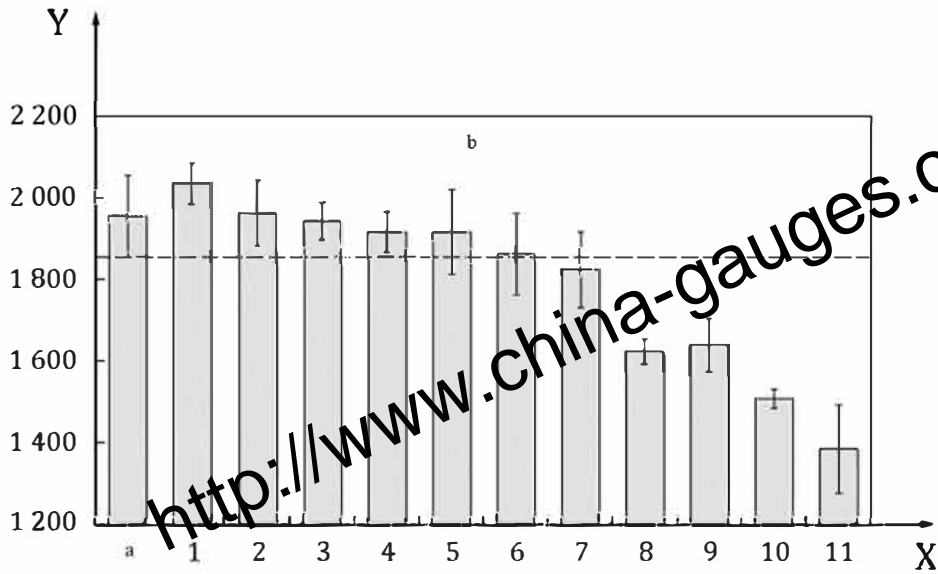
See Table C.1.

**Table C.1 — Material used for evaluation**

Fibre	PAN based carbon fibre
Matrix	Polyamide 6
Fibre volume fraction	approx. 43 %
Tape thickness	0,18 mm
Moulding process	Hot press
Number of layers	7
Specimen number	5

**Table C.2 — Comparison of test methods for unbonded tabs (emery papers), and gripping condition without tabs using fine grip faces**

Gripping conditions	1	2	3	4	5	6	7	8	9	10	11
Force control: H = Hydraulic M = Manual screw	M	H	M :Precise	H :Precise	H	H	M	M :Precise	H	M :Precise	M
Roughness of grip face: L = Large (>1 mm) M = Middle (<1 mm) F = Fine (<0,25 mm)	M	F	F	F	M	F	M	M	M	L	M
Abrasive paper? Y = Yes N = No	Y :double	Y	N	N	Y	N	Y	N	N	N	N



**Key**

- X gripping condition
- Y tensile failure strength (MPa)
- a Tabs.
- b Error bars = Standard deviation.

**Figure C.1 — Comparison of maximum stress (strength) at final fracture of specimen**

## Annex D (normative)

### Specimen preparation for type 2 and type 3

#### D.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.
- Machine the specimens in accordance with ISO 2818.

#### D.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.

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

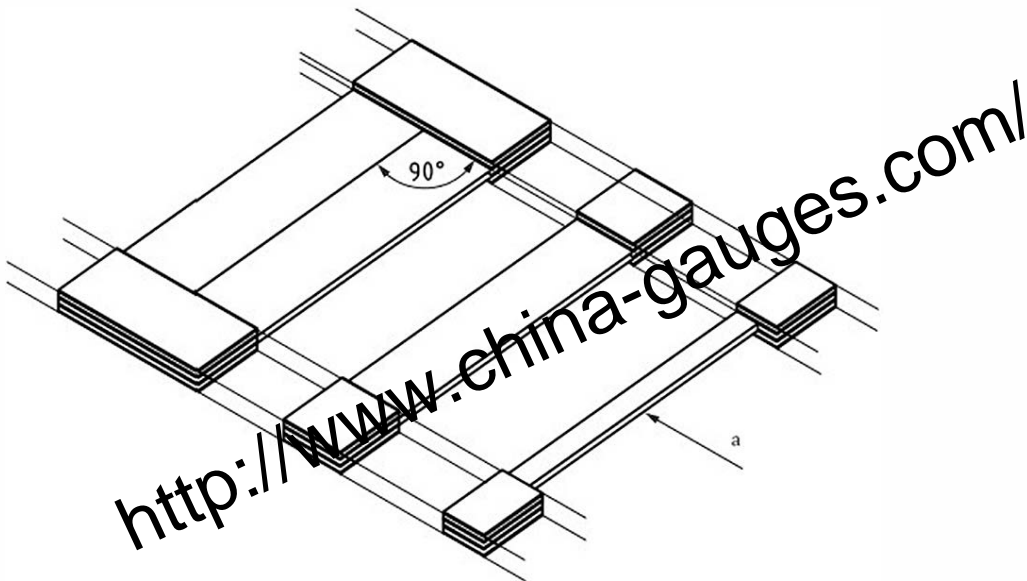
Cut out rectangular strips of the required length and width for the tabs.

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 D.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 D.1](#)).



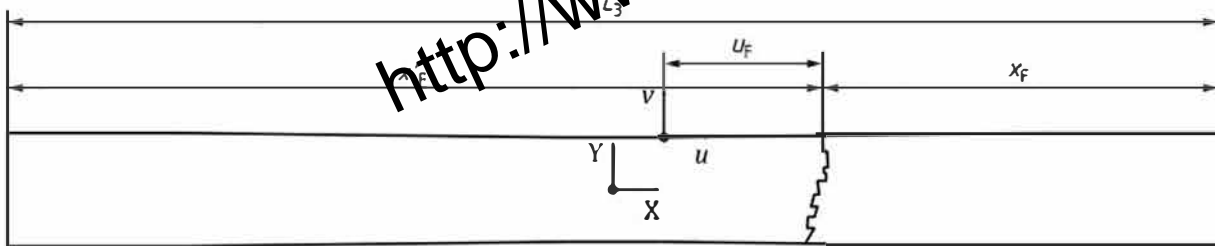
<sup>a</sup> Trimmed to waste.

**Figure D.1 — Tabbed panel for specimen preparation**

**Annex E**  
 (normative)

**Failure location related calculation of tensile strength for type 4 specimens**

**E.1 Estimation of the failure location  $u_F$  within specimen**



**Key**

- $L_3$  specimen length
- $u_F$  initial failure location
- $x_F$  shortest distance of the fractured specimen piece
- $x'_F$  longest distance of the fractured specimen piece

**Figure E.1 — Estimation of the failure location  $u_F$  within specimen type 4**

If the initial failure location  $u_F$  is not determined by video capturing, the failure location  $u_F$  is calculated by measuring the shortest distance  $x_F$  or the longest distance  $x'_F$  of the fractured specimen's pieces (see [Figure E.1](#)) and using [Formulae \(E.1\)](#) and [\(E.2\)](#).

Failure location  $u_F$  estimated by the shortest distance according to [Formula \(E.1\)](#):

$$u_F = \frac{L_3}{2} - x_F - 12,5 \quad (\text{E.1})$$

Failure location  $u_F$  estimated by the longest distance according to [Formula \(E.2\)](#):

$$u_F = x'_F - \frac{L_3}{2} - 12,5 \quad (\text{E.2})$$

where

- $L_3$  is the total length of specimen (in mm);
- $x_F$  is the shortest distance of failure initiation point from end of specimen in  $x$ -direction, in millimetres (mm);
- $x'_F$  is the longest distance of failure initiation point from end of specimen in  $x$  direction, in millimetres (mm);
- $u_F$  is the failure location within the Bézier curve's coordinate system, in millimetres (mm).



## E.2 Calculation of the fracture cross section ratio $c_{Fr}$

Fracture cross section ratio  $c_{Fr}$  is calculated according to [Formula \(E.3\)](#) or by using [Figure E.2](#):

$$c_{Fr} = \frac{b_1}{b_1 + \Delta b(u_F)} \quad (E.3)$$

where

- $b_1$  is the measured width of specimen in parallel middle area, in millimetres (mm);
- $\Delta b$  is the specimen width deviation from the parallel midsection at the position  $u_F$  within specimen type 4, in millimetres (mm);
- $c_{Fr}$  is the fracture cross section ratio, the ratio of the cross section of the parallel midsection and the fractured cross section.

Specimen width deviation from the parallel midsection at the position  $u_F$  can be approximated within the boundary of  $0 \leq u_F \leq 87,5$ :

$$\Delta b(u) = \tan^{-1}(0,060\ 47u)0,024\ 6u \quad (E.4)$$

For  $u_F < 0$ :

$$\Delta b(u) = 0$$

If the fracture position  $u_F$  is greater than 87,5 mm the tested specimen result is invalid.

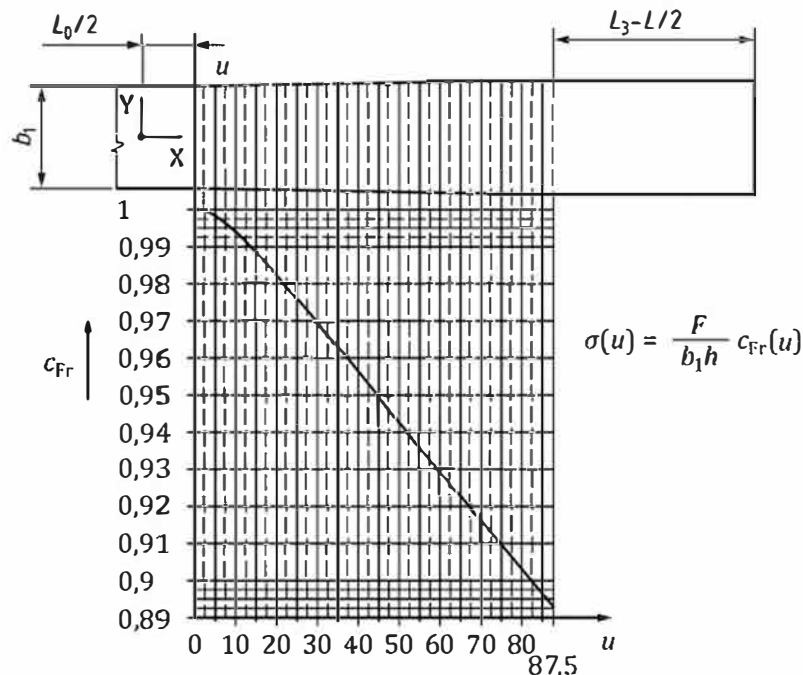


Figure E.2 — Fracture cross section ratio  $c_{Fr}$  of specimen type 4

### E.3 Calculation of the tensile strength $\sigma_m$

Tensile strength at failure location is calculated as shown in [Formula \(E.5\)](#):

$$\sigma_m = \frac{F}{b_1 h} c_{Fr} \quad (E.5)$$

with

- $F$  is the tensile force at failure initiation, in Newton (N);
- $h$  is the specimen thickness, in millimetres (mm);
- $\sigma_m$  is the tensile strength at failure location, in megapascal (MPa).

### E.4 Tensile strain estimation at failure position $u_F > 0$

Due to the dominant elastic nature of continuous fibre-reinforced composites the stress-strain curve can be obtained from the measurement area even though the specimen failed within the tapered section. There are two options to determine the tensile strain at failure position.

The recommended option of calculation is according to [Formula \(E.6\)](#).

Tensile strain at the failure location  $\epsilon_m$  is estimated by evaluating the equivalent tensile strain value for  $\sigma_m$  in the measured  $\sigma$ - $\epsilon$  curve data by interpolation between two data points  $\sigma_i, \epsilon_i$  and  $\sigma_{i+1}, \epsilon_{i+1}$ .

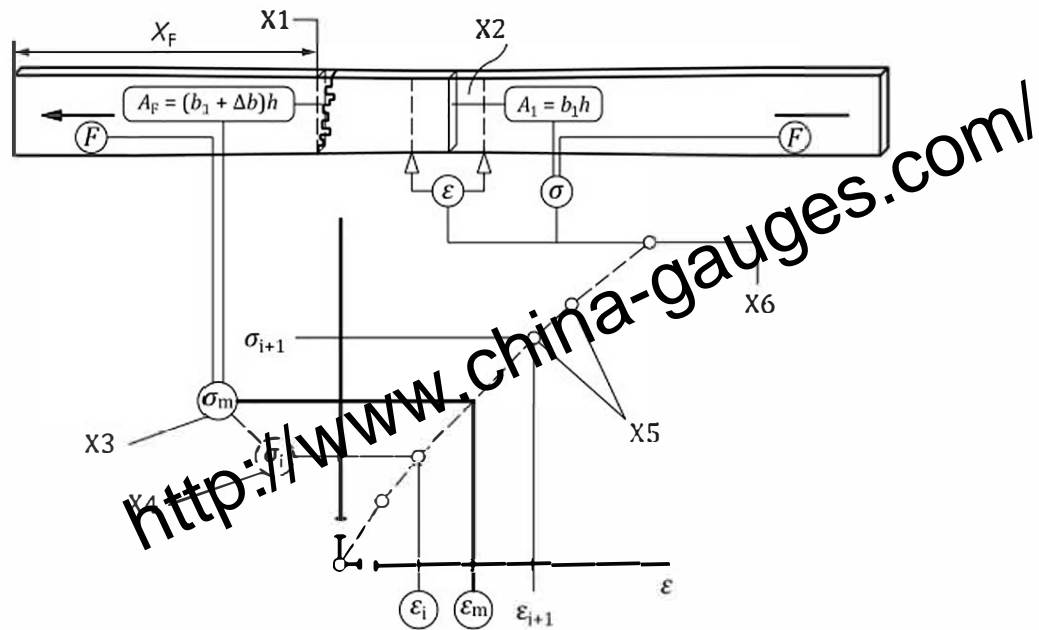
$$\epsilon_m(\sigma_m) = \begin{cases} \epsilon_m, & \text{if } u \leq 0 \\ \epsilon_i + \frac{\epsilon_{i+1} - \epsilon_i}{\sigma_{i+1} - \sigma_i} (\sigma_m - \sigma_i), & \text{else if } u > 0 \text{ for } i^{\text{th}} \text{ data point } \sigma_i < \sigma_m < \sigma_{i+1} \end{cases} \quad (E.6)$$

where

- $\sigma_m$  is the tensile strength at failure location, in megapascal (MPa);
- $\sigma_i$  is the tensile stress at the  $i^{\text{th}}$  line of the  $\sigma$ - $\epsilon$  curve, in megapascal (MPa);
- $\epsilon_i$  is the strain data point at the  $i^{\text{th}}$  line of the  $\sigma$ - $\epsilon$  curve.

If the data points  $\sigma_i$  and  $\sigma_{i+1}$  have a distance below  $0,001 \sigma_m$  the next lower data point  $\sigma_j, \epsilon_j$  can be selected as tensile strength and tensile failure strain.

An alternative option is to take the nearest data point to  $\sigma_m$  within the measured data. As shown in [Figure E.3](#) the stress at the failure position is determined by measuring the distance  $x_F$  (or  $x'_F$ ) and determining  $\sigma_m$ . The next lower data point ( $\epsilon_i, \sigma_i$ ) to  $\sigma_m$  defines the tensile strain  $\epsilon_m$  and stress  $\sigma_m$  at the failure position. For this alternative option, a data point resolution of  $0,001 \sigma_{max}$  is recommended.



**Key**

- X1 failure location with a failure cross section  $A_F$
- X2 measurement area for strain estimation
- X3 option 1; interpolation of  $\epsilon_F$
- X4 option 2; selection of  $(\epsilon_i, \sigma_i)$  as new  $(\epsilon_m, \sigma_m)$
- X5 data points of stress strain curve
- X6 stress-strain data point of measurement area at specimen's failure
- $F$  applied tensile force ● on specimen
- $A_F$  area of final specimen failure
- $A_1$  area of specimen's midsection

**Figure E.3 — Tensile strain estimation for failure position using the  $\sigma$ - $\epsilon$  curve data of the specimen's type 4 measurement area**

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1) Withdrawn and replaced by ISO 6344-2:2021 and ISO 6344-3:2021.

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