AS 1145.4—2001
ISO 527-4:1997



Australian Standard™

# Determination of tensile properties of plastics materials

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

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

Standards Australia

This Australian Standard was prepared by Committee PL-010, Methods of Testing Plastics. It was approved on behalf of the Council of Standards Australia on 27 October 2000 and published on 27 February 2001.

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CSIRO Building, Construction and Engineering

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# Determination of tensile properties of plastics materials

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# PREFACE

This Standard was prepared by the Standards Australia Committee PL-010, Methods of Testing Plastics.

This Standard is identical to and is reproduced from ISO 527-4:1997, *Determination of tensile properties of plastics materials*, Part 4: *Test conditions for isotropic and orthotropic fibre-reinforced plastic composites.*

The objective of this Standard is to provide a test method for tensile testing of plastics materials.

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(a) Its number does not appear on each page of text and its identity is shown only on the cover and title page.

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| *Reference to International Standard* | | *Australian or Australian/New Zealand Standard* | |
|---|---|---|---|
| ISO/IEC | | AS/NZS | |
| 527 | Plastics—Determination of tensile properties | 1145 | Determination of tensile properties of plastics materials |
| 527-1 | Part 1: General principles | 1145.1 | Part 1: General principals |
| 527-2 | Part 2: Test conditions for moulding and extrusion plastics | 1145.2 | Part 2: Test conditions for moulding and extrusion plastics |
| 527-5 | Part 5: Test conditions for unidirectional fibre-reinforced plastic composites | 1145.5 | Part 5: Test conditions for unidirectional fibre-reinforced plastic composites |
| 1268 | Plastics — Preparation of glass fibre reinforced, resin bonded, low-pressure laminated plates or panels for test purposes. | | — |
| 2818 | Plastics — Preparation of test specimens by machining. | | — |
| 3534 | Statistics — Vocabulary and symbols — Part 1: Probability and general statistical terms. | | — |

AUSTRALIAN STANDARD

# Determination of tensile properties of plastics materials

## Part 4:
## Test conditions for isotropic and orthotropic 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 isotropic and orthotropic fibre-reinforced plastic composites, based upon the general principles given in part 1.

Unidirectionally reinforced materials are covered by part 5.

**1.2** See ISO 527-1, subclause 1.2.

**1.3** 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 preimpregnated materials (prepregs) (for directly injection-moulded specimens, see specimen 1A in ISO 527-2:1993);

— combinations of the above with unidirectional reinforcements and multidirectional reinforced materials constructed from unidirectional layers, provided such laminates are symmetrical (for materials with completely, or mainly, unidirectional reinforcements, see ISO 527-5);

— finished products made from these materials.

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

**1.4** The method is performed using specimens machined from a test panel made in accordance with ISO 1268 or by equivalent methods, or from finished and semi-finished products with suitable flat areas.

**1.5** See ISO 527-1, subclause 1.5.

## 2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 527. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 527 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 527-2:1993, *Plastics — Determination of tensile properties — Part 2: Test conditions for moulding and extrusion plastics.*

ISO 527-5:1997, *Plastics — Determination of tensile properties — Part 5: Test conditions for unidirectional fibre-reinforced plastic composites.*

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

ISO 2818:1994, *Plastics — Preparation of test specimens by machining.*

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

## 3 Principle

See ISO 527-1, clause 3.

## 4 Definitions

For the purposes of this part of ISO 527, the following definitions apply.

**4.1 gauge length:** See ISO 527-1, subclause 4.1.

**4.2 speed of testing:** See ISO 527-1, subclause 4.2.

**4.3 tensile stress,** $\sigma$ (engineering): See ISO 527-1, subclause 4.3, except that $\sigma$ for "1"-direction specimens is defined as $\sigma_1$ and for "2"-direction specimens as $\sigma_2$ (see 4.8 for definitions of these directions).

**4.3.1 tensile strength,** $\sigma_M$: See ISO 527-1, subclause 4.3.3, except that $\sigma_M$ for "1"-direction specimens is defined as $\sigma_{M1}$ and for "2"-direction specimens as $\sigma_{M2}$.

**4.4 tensile strain,** $\varepsilon$: See ISO 527-1, subclause 4.4, except that $\varepsilon$ for "1"-direction specimens is defined as $\varepsilon_1$ and for "2"-direction specimens as $\varepsilon_2$.

It is expressed as a dimensionless ratio or in percent.

**4.5 tensile strain at tensile strength; tensile failure strain,** $\varepsilon_M$: The tensile strain at the point corresponding to the tensile strength of the specimen.

For "1"-direction specimens, $\varepsilon_M$ is defined as $\varepsilon_{M1}$ and for "2"-direction specimens as $\varepsilon_{M2}$.

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, subclause 4.6, except that $E$ for "1"-direction specimens is defined as $E_1$ and for "2"-direction specimens as $E_2$.

The strain values used are as given in ISO 527-1, 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,** $\mu$: See ISO 527-1, subclause 4.7, except that for "1"-direction specimens $\mu_b$ is defined as $\mu_{12}$ and $\mu_h$ as $\mu_{13}$, using the coordinates shown in figure 2. For "2"-direction specimens, $\mu_b$ is defined as $\mu_{21}$ and $\mu_h$ as $\mu_{23}$.

**4.8 specimen coordinate axes:** The "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). The "2"-direction is perpendicular to the "1"-direction.

NOTES

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

2 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 fibres) as the "2"-direction.

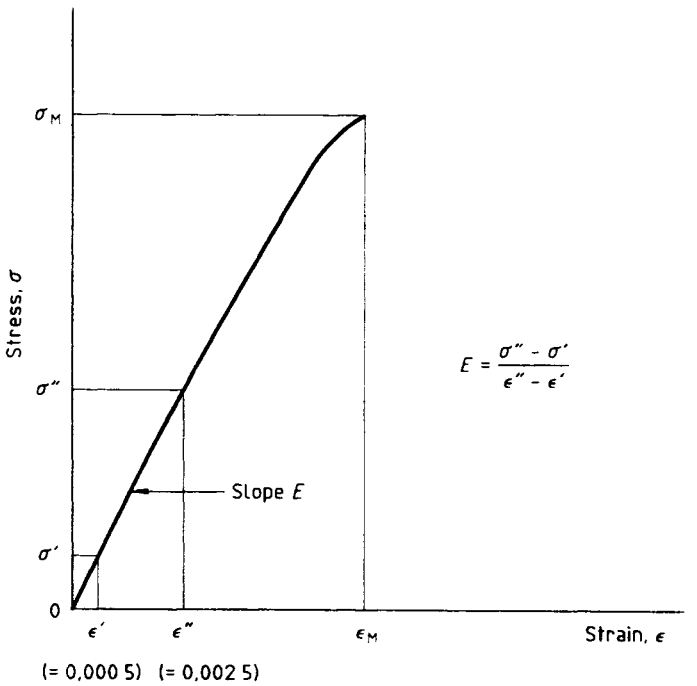



**Figure 1 — Stress-strain curve**

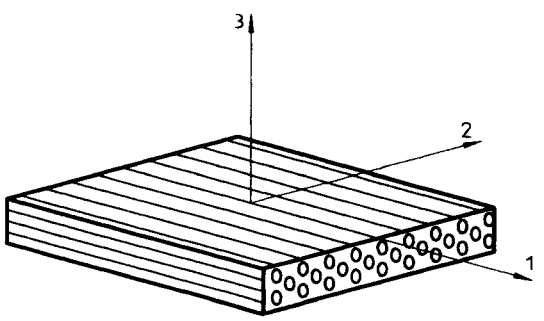



**Figure 2 — Fibre-reinforced plastic composite showing axes of symmetry**

## 5 Apparatus

See ISO 527-1, 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.

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

Three types of test specimen are specified for use with this part of ISO 527, as detailed and illustrated in figure 3 (type 1B) and figure 4 (types 2 and 3).

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.

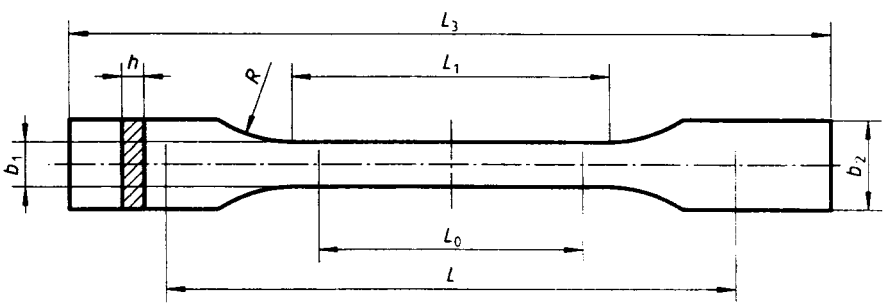
Type 2 (rectangular without end tabs) and type 3 (rectangular with bonded end tabs) are for testing fibre-reinforced thermosets and thermoplastics. Specimens with unbonded end tabs are considered as type 2.

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.

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

To decide whether to use type 2 or type 3 specimens, first carry out tests with type 2 specimens and, if the test is not possible or not satisfactory, i.e. if the specimen slips or breaks in the grips (see ISO 527-1, subclause 5.1), use type 3 specimens.

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 %.




Dimensions in millimetres

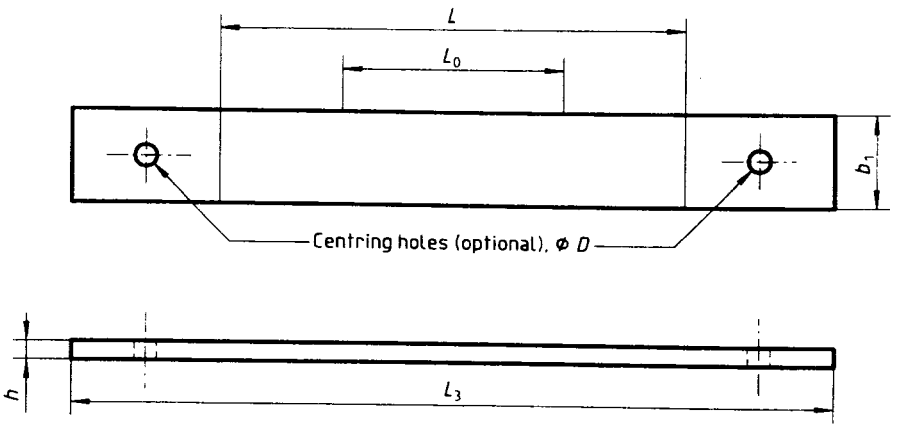
| | | |
|---|---|---|
| $L_3$ | Overall length | ⩾ 150 [1] |
| $L_1$ | Length of narrow parallel-sided portion | 60 ± 0,5 |
| $R$ | Radius | ⩾ 60 [2] |
| $b_2$ | Width at ends | 20 ± 0,2 |
| $b_1$ | Width of narrow portion | 10 ± 0,2 |
| $h$ | Thickness | 2 to 10 |
| $L_0$ | Gauge length (recommended for extensometers) | 50 ± 0,5 |
| $L$ | Initial distance between grips | 115 ± 1 |

NOTE — Requirements on specimen quality and parallelism are given in clause 6.

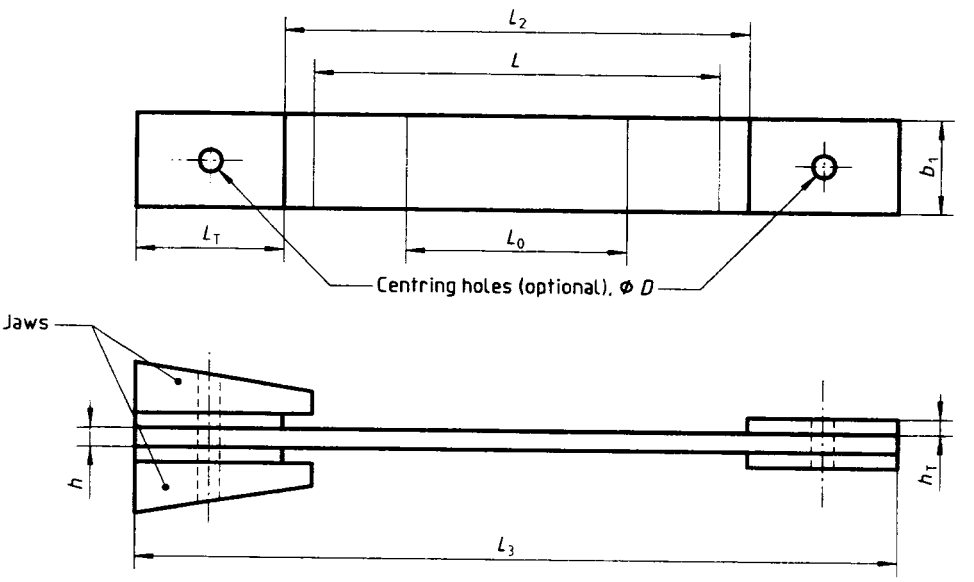
1) For some materials, the length of the tabs may need to be extended (e.g. so that $l_3$ = 200 mm) to prevent breakage or slippage of the specimen in the jaws.

2) 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 and ISO 3167:1993, *Plastics — Multipurpose test specimens.*

**Figure 3 — Type 1B specimen**




a) Type 2 specimen




b) Type 3 specimen

Dimensions in millimetres

| | | Type 2 | Type 3 |
|---|---|---|---|
| $L_3$ | Overall length | ⩾ 250 | ⩾ 250 |
| $L_2$ | Distance between end tabs | — | 150 ± 1 |
| $b_1$ | Width | 25 ± 0,5 or 50 ± 0,5 | 25 ± 0,5 or 50 ± 0,5 |
| $h$ | Thickness | 2 to 10 | 2 to 10 |
| $L_0$ | Gauge length (recommended for extensometers) | 50 ± 1 | 50 ± 1 |
| $L$ | Initial distance between grips | 150 ± 1 | 136 (nominal) |
| $L_T$ | Length of end tabs | — | ⩾ 50 |
| $h_T$ | Thickness of end tabs | — | 1 to 3 |
| $D$ | Diameter of centring holes | 3 ± 0,25 | 3 ± 0,25 |

NOTE — Requirements on specimen quality and parallelism are given in clause 6.

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

## 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 or another specified/agreed procedure. Cut individual specimens, or groups of specimens in the case of type 3 specimens (see annex A), 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 are specified in ISO 2818. Further guidance on cutting specimens is given in annex A.

### 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 ± 45° to the specimen axis. The tab thickness shall be between 1 mm and 3 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, 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).

### 6.2.3 Application of end tabs (for type 3 specimens)

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, subclause 6.3.

## 6.4 Checking the specimens

See ISO 527-1, subclause 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 subclause 4.8).

# 7 Number of specimens

See ISO 527-1, clause 7.

# 8 Conditioning

See ISO 527-1, clause 8.

# 9 Procedure

## 9.1 Test atmosphere

See ISO 527-1, subclause 9.1.

## 9.2 Measurement of specimen dimensions

See ISO 527-1, subclause 9.2.

## 9.3 Clamping

See ISO 527-1, subclause 9.3.

## 9.4 Prestresses

See ISO 527-1, subclause 9.4.

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

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

## 9.6 Test speed

Use the following test speeds:

### 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 and type 3 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

See ISO 527-1, subclause 9.7.

# 10 Calculation and expression of results

See ISO 527-1, 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.

If Poisson's ratio is required, calculate it at the strain values given in 4.6.

## 11 Precision

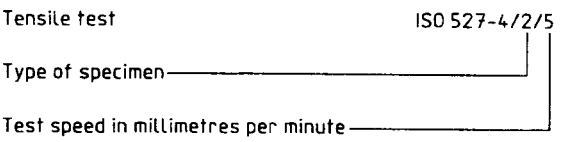
The precision of this test method is not known because interlaboratory data are not available. When interlaboratory data are obtained, a precision statement will be added with the following revision.

The precision data will be specific to particular combinations of fibre and matrix types.

## 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:




b) to q) see ISO 527-1, clause 12, b) to q), including fibre type, fibre content and fibre geometry (e.g. mat) in 12b).

# 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.

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

NOTE — 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).

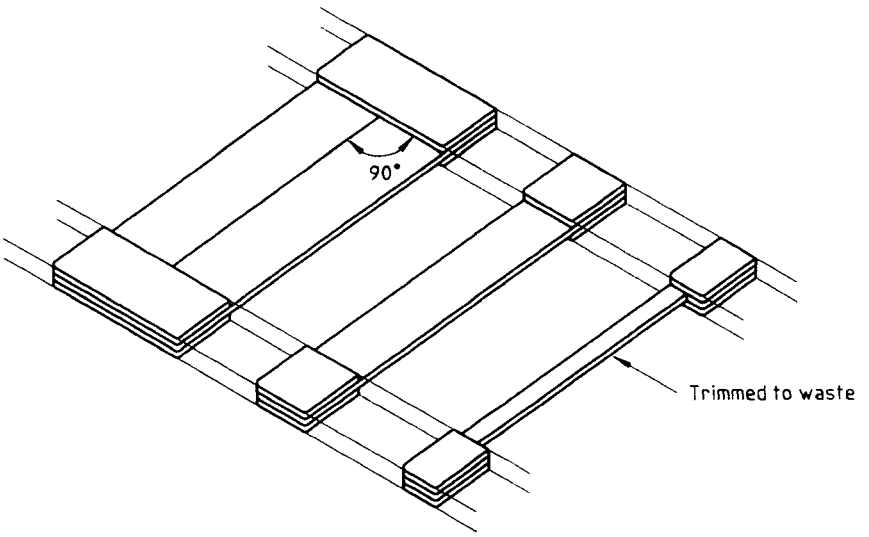



**Figure A.1 — Tabbed panel for specimen preparation**

# 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.

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

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

where

$\varepsilon_1$, $\varepsilon_2$ and $\varepsilon_3$ 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):

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

NOTES

1 The use of further strain gauges next to the grips will be necessary to check fully all possible sources of misalignment.

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.

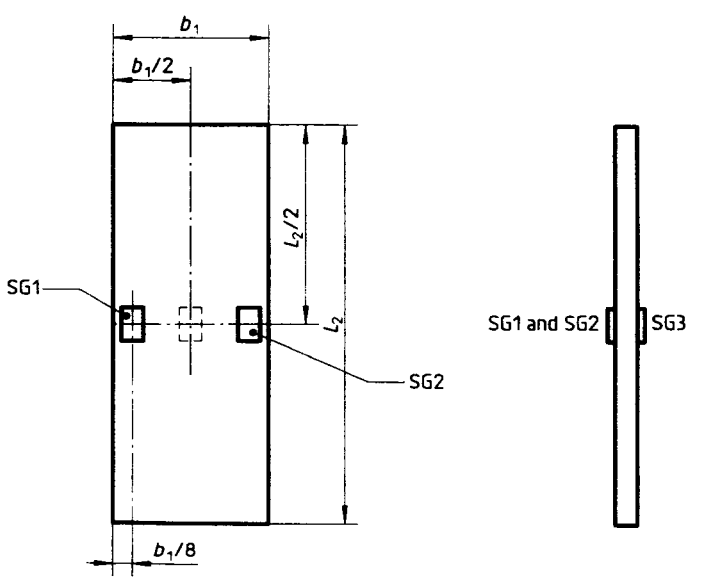



**Figure B.1 — Strain-gauge locations (SG1, SG2 and SG3) for system alignment check**

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