INTERNATIONAL STANDARD

ISO 11003-1

Second edition
2001-12-01

Adhesives — Determination of shear behaviour of structural adhesives —

Part 1: **Torsion test method using butt-bonded hollow cylinders**

Adhésifs — Détermination du comportement en cisaillement d'adhésifs structuraux —

Partie 1: Méthode d'essai en torsion de cylindres creux collés bout à bout

Reference number
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Contents

Page

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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

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 part of ISO 11003 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 11003-1 was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 11, *Products*.

This second edition cancels and replaces the first edition (ISO 11003-1:1993), which has been technically revised.

ISO 11003 consists of the following parts, under the general title *Adhesives — Determination of shear behaviour of structural adhesives*:

— *Part 1: Torsion test method using butt-bonded hollow cylinders*

— *Part 2: Tensile test method using thick adherends*

Adhesives — Determination of shear behaviour of structural adhesives —

Part 1:
Torsion test method using butt-bonded hollow cylinders

1 Scope

This part of ISO 11003 specifies a shear test for the characterization of adhesives in a bond. The shear stress/strain properties of the adhesive (including the shear modulus) are useful for advanced design work, e.g. in finite element analysis methods.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 11003. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 11003 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 291:1997, *Plastics — Standard atmospheres for conditioning and testing*

ISO 4588:1995, *Adhesives — Guidelines for the surface preparation of metals*

ISO 10365:1992, *Adhesives — Designation of main failure patterns*

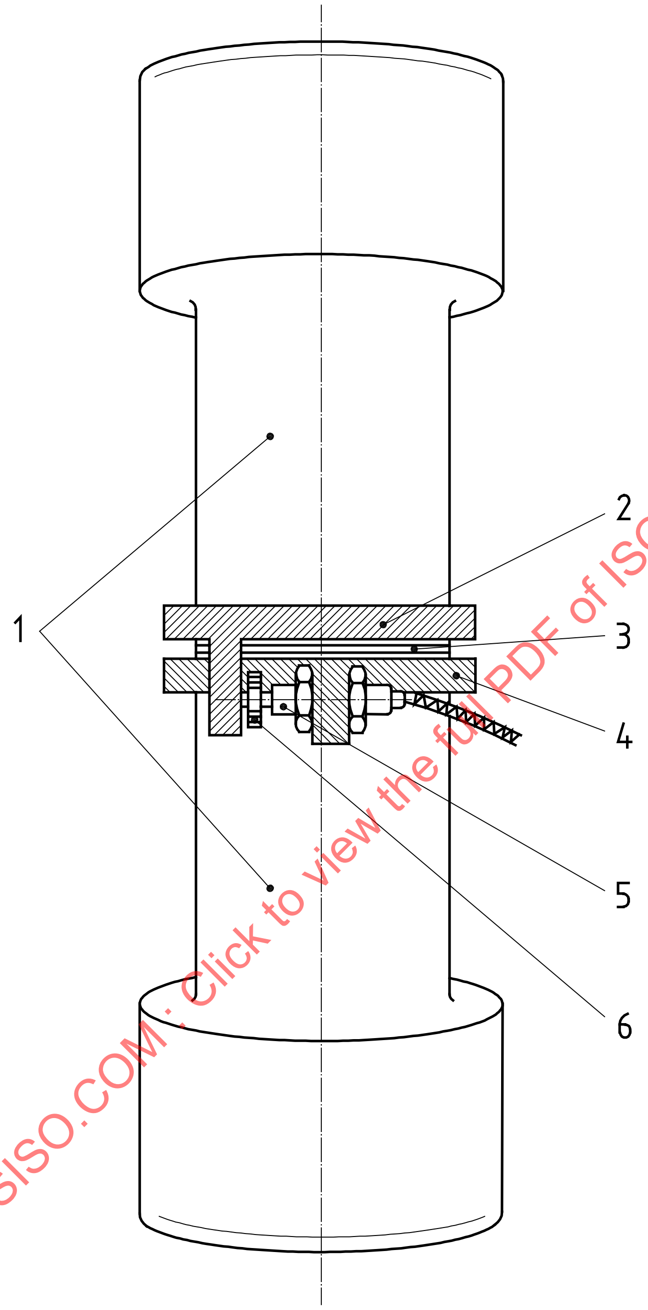
3 Principle

The shear deformation of the adhesive in an annular bond between two hollow cylinders, and the corresponding torque, are measured and recorded up to failure of the joint.

4 Apparatus

4.1 Torsion-testing machine, with a capacity of at least 300 N·m and preferably of 1 000 N·m. Alternatively, a suitably adapted tensile-testing machine may be used. The machine shall include equipment for recording the torque instantaneously with an error of less than 1 %. The gripping heads shall be accurately aligned and, if no hydraulic gripping mechanism is available, all bolts and holes shall be precisely machined so that the specimens are mounted in the apparatus and tested free of uncontrolled loads. The machine shall be equipped with an adequately thermostatted chamber if tests are to be carried out at temperatures different from the ambient temperature.

4.2 Displacement sensor (see Figure 1), capable of measuring, as near as possible to the bond line, the displacement of the two adherends relative to each other and hence the deformation of the adhesive. The sensor and its associated target shall be rigidly mounted on the two adherends as shown in Figure 1. The range of the displacement-measuring equipment shall be adjustable to permit the full-scale reading to be varied between 2 μm and 1 000 μm. The equipment shall be capable of measuring displacements to an accuracy of ± 1 μm. The sensor shall be of lightweight and robust construction since it is subjected to high accelerations on failure of the specimen.



Key

1 Adherends
2 Target support (on upper adherend)
3 Butt joint
4 Transducer support (on lower adherend)
5 Displacement transducer
6 Target

Figure 1 — Adhesive-layer specimen with displacement transducer mounted in the test apparatus

5 Test specimen

5.1 Preparation

5.1.1 Substrate material

Aluminium alloy or steel are suitable materials for the adherends. Other materials are acceptable provided the material (including pre-treated surface layers) has a shear modulus at least ten times higher than that of the adhesive.

5.1.2 Preparation of the surface

The surfaces to be bonded shall be prepared in accordance with ISO 4588 or by any method leading to a cohesive failure within the adhesive layer.

5.1.3 Bonding

Prepare the specimens in accordance with the instructions of the manufacturer of the adhesive. Information about conditioning of the specimen shall be included in the test report.

A joint completely filled with adhesive is essential for the reliability of the test. The two adherends shall be bonded coaxially, with a maximum lateral displacement between their two axes of 0,002 r_o (r_o = outer radius), and a maximum angular deviation so that the bond line thickness varies by no more than 5 % of the recommended thickness. The joining device shall prevent the adhesive from running out of the joint and any displacement of the two adherends during curing.

NOTE To achieve this, the two hollow cylinders may be aligned with the help of a plug made of polytetrafluoroethylene (PTFE) or any other suitable device. A temperature-resistant O-ring, inserted into the PTFE plug and placed just below the bond, stops the adhesive from running out of the joint. At the other ends of the adherends, two plates fastened to a threaded rod passing through the PTFE plug prevent any displacement during curing (see Figure 2).

5.1.4 Adhesive bond

The preferred thickness of the bond is 0,2 mm.

NOTE For special adhesives, a thickness in the range from 0,05 mm to 0,5 mm may be used.

The thickness of the bond is defined by a rim which is machined along the outer perimeter of one adherend. The rim acts as spacer between the two adherends. The adhesive is applied to the machined adherend to fill the space adjacent to the rim, prior to joining the two adherends. The rim is removed on the lathe after the adhesive is cured (see Figure 3). The resulting adhesive layer shall have a width at least ten times its thickness.

5.1.5 Dimensions

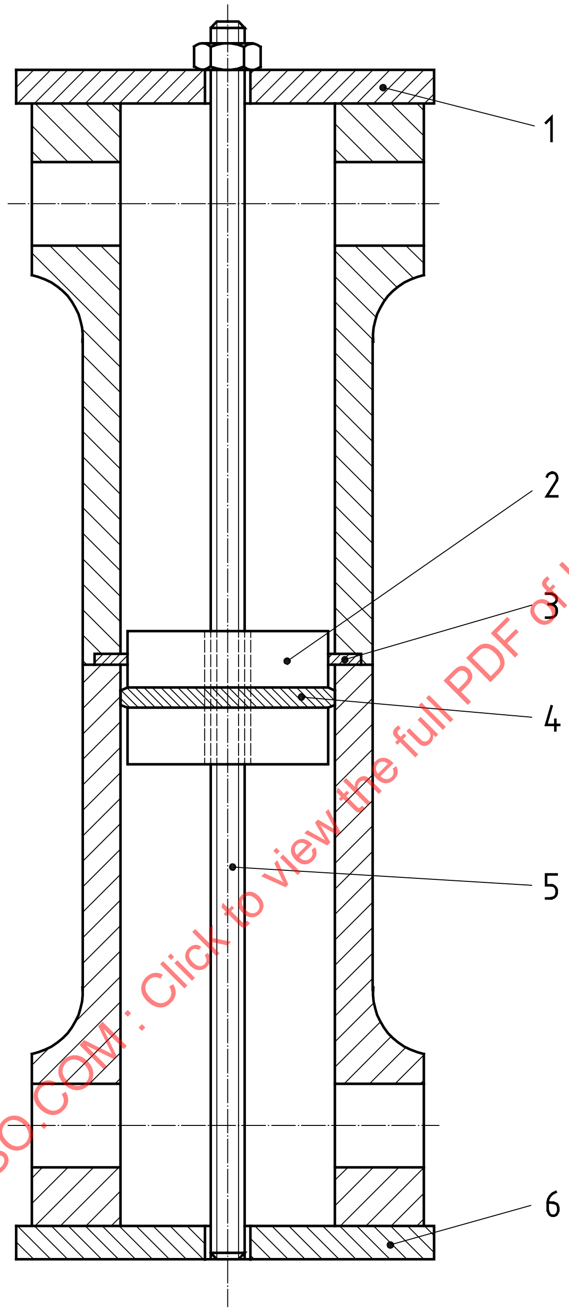
Three sizes of specimen (A, B, C) are recommended (see Table 1), although intermediate sizes are acceptable provided that

$$r_i \geqslant 0{,}8\, r_o$$

where

r_i is the inner radius of each cylinder;

r_o is the outer radius of each cylinder.

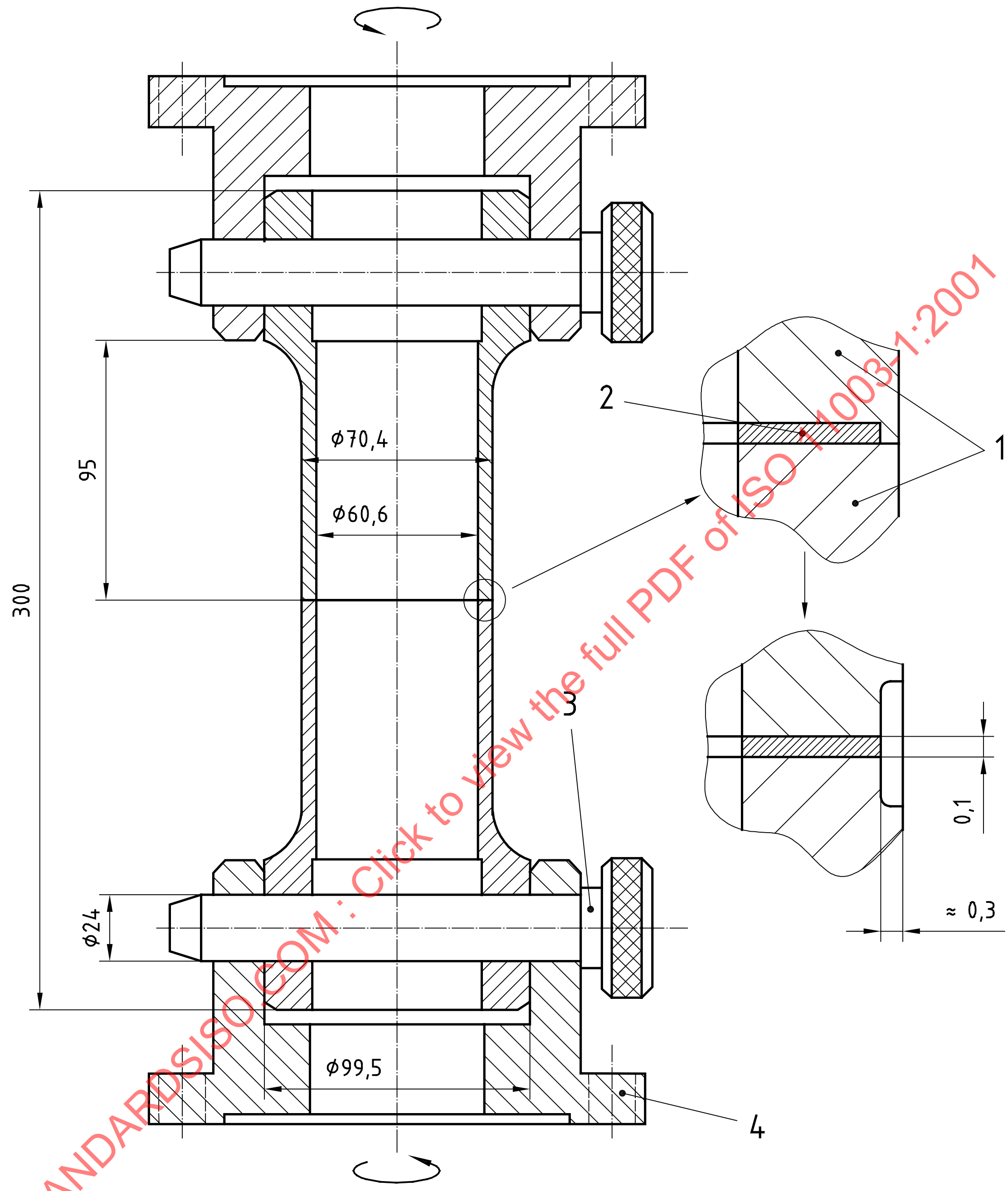


Key

1 Top plate
2 Polytetrafluoroethylene plug
3 Adhesive layer
4 O-ring
5 Rod with screw thread
6 Bottom plate

Figure 2 — Coaxially aligned hollow cylinders in a suitable joining device

Dimensions in millimetres



Key

1 Adherends

2 Adhesive

3 Bolt

4 Fixture

NOTE The rim spacer that controls the thickness of the bond is shown in the upper detail view. Before testing, the spacer is removed, as shown in the lower detail view.

Figure 3 — Dimensions of the specimen and specimen holders

The width ($r_i - r_o$) of the bond zone may be reduced to a minimum of 0,1 r_o if the available torque is not sufficient to produce failure of the specimen.

Suitable values for the length of the specimen and the dimensions of the specimen holders are given in Figure 3.

The thickness of the bond is controlled by a spacer (see 5.1.4 and Figure 3).

Table 1 — Recommended specimen sizes

Specimen	Radii	
	r_i mm	r_o mm
A	36	30
B	24	20
C	12	10

5.2 Number of specimens

At least five specimens shall be tested for a given adhesive.

6 Test conditions

6.1 Temperature

The temperature of the test shall be one of the standard temperatures specified in ISO 291. The temperature of the specimen shall be measured at the outer surface of the hollow cylinder, close to the bond (e.g. with thermocouples). Agreement to within $\pm 1\ ^\circ$C is required.

6.2 Shear rate

The rate of shear $\dot{\gamma}$ of the adhesive shall lie within the range from 0,000 5 s^{-1} to 0,02 s^{-1}.

NOTE The preferred rate of shear is 0,01 s^{-1}.

The corresponding rate of angular displacement $\dot{\alpha}$ to be set on the torsion-testing machine is given by the equation:

$$\dot{\alpha} = \frac{\dot{\gamma} d}{r_o}$$

where

d is the thickness of the adhesive bond, expressed in millimetres;

r_o is the outer radius of the specimen, expressed in millimetres (see Table 1).

7 Procedure

Fix the specimens in the test apparatus, equipped with a temperature cabinet if required. Adjust the apparatus so that the joint is free from any load.

While increasing the shear deformation continuously up to the requested maximum value, record the torque-displacement curve. If the specimen fails, check the surfaces of the bonded parts and reject any specimens with incompletely filled adhesive bonds (due e.g. to the presence of bubbles or voids). Sometimes the adhesive layer will not fail after reaching the maximum shear deformation, especially when loading with a low shear rate. If this happens, repeat the test with an increasing torque rate until the specimen fails. As before, check the adhesive layer for defects of fabrication. Ensure that cohesive failure is achieved.

8 Calculations

8.1 The shear stress τ, expressed in megapascals, in the bond line close to the outer radius is given by the equation:

$$\tau = \frac{2}{\pi} \times \frac{M r_o}{r_o^4 - r_i^4}$$

where

M is the torque, expressed in newton millimetres, acting across the joint;

r_o is the outer radius, expressed in millimetres, of the cylinders;

r_i is the inner radius, expressed in millimetres, of the cylinders.

8.2 The displacement d_m measured during the test is composed of the displacement d_a of the adhesive and the displacement d_t due to the twist of the two adherends (see Figure 4). Therefore, the shear strain γ in a bond of thickness t is given by the equation:

$$\tan \gamma = \frac{d_a}{t} = \frac{d_m - d_t}{t} \cong \gamma$$

where d_a, d_m, d_t and t are measured in millimetres.

d_t is calculated from the shear modulus G_t of the adherend material and the shear stress acting in the adherends (alternatively, the deformation of the adherends d_t may be determined experimentally at the appropriate temperatures for an unbonded specimen made of the same material and having the same dimensions).

8.3 The shear modulus G_a $(= \tau/\gamma)$ of the adhesive is determined from the slope of the initial linear portion of the stress-strain curve.

8.4 Calculate the arithmetic mean of the results and the standard deviation for the shear modulus, as well as the highest shear stress (shear strength) and corresponding shear strain and, if applicable, the shear stress and strain at specimen failure.

9 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 at the following revision.