INTERNATIONAL STANDARD

ISO 11003-1

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Adhesives — Determination of shear behaviour of structural bonds —

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

Adhésifs — Détermination du comportement en cisaillement de joints structuraux —

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

Reference number
ISO 11003-1:1993(E)

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.

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.

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

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

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

— *Part 2: Thick-adherend tensile-test method*

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Adhesives — Determination of shear behaviour of structural bonds —

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

1 Scope

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

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 11003. 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 11003 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 291:1977, *Plastics — Standard atmospheres for conditioning and testing.*

ISO 4588:1989, *Adhesives — Preparation of metal surfaces for adhesive bonding.*

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

3 Principle

The deformation of the adhesive in the annular bond between two butt-jointed hollow cylinders is determined as a function of the applied torque up to failure of the joint. The circular symmetry of the specimen entails a state of simple shear with uniform strain in the bond line. In principle, there are no peaks in the stress distribution curve, since the bond is continuous in the direction of the displacement.

4 Apparatus

4.1 Torsion testing machine, with a capacity of 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 cardan joints shall be accurately aligned and all bolts and holes 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 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. Sensor sensitivity shall be adjustable to permit the full-scale reading to be varied between 2 µm and 1 000 µm. Sensor resolution shall be 1,2 µm or better, and the error in readings above 30 % of full scale shall not be greater than ± 5 % in any sensitivity range. The sensor shall be of light weight and robust construction since it is subjected to high accelerations on failure of the specimen.

5 Specimen

5.1 Substrate material

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

5.2 Preparation of the surface

The surfaces to be bonded shall be prepared in accordance with ISO 4588, unless otherwise specified.

5.3 Bonding

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

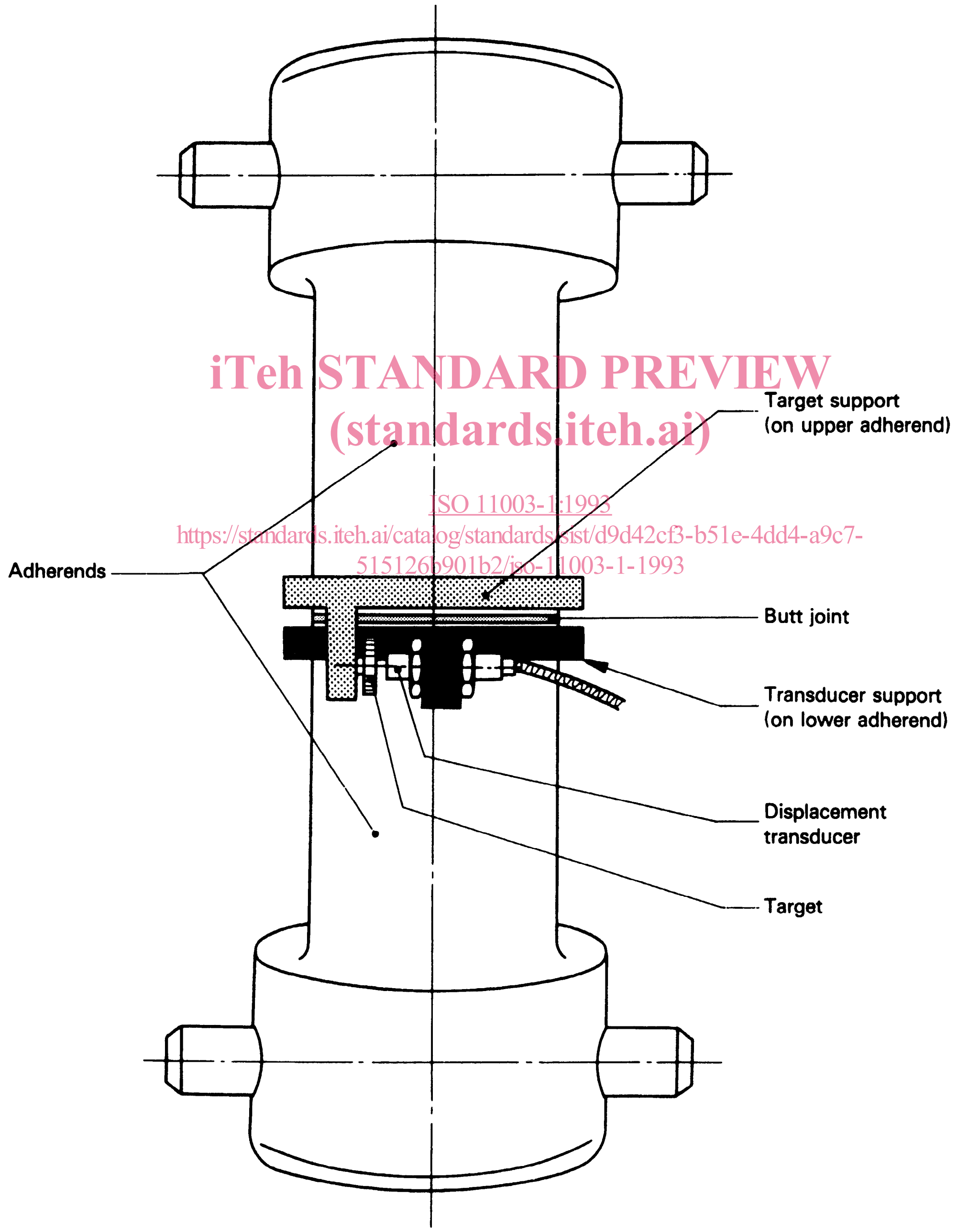


Figure 1 — Butt-joint specimen with displacement transducer fixed in the testing apparatus

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 $0{,}02r_0$. To achieve this, the two hollow cylinders may be aligned with the help of a plug made of polytetrafluoroethylene (PTFE).

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).

5.4 Adhesive bond

The preferred thickness of the bond is 0,1 mm ± 5 µm. Any deviations from this range of values shall be indicated in the test report.

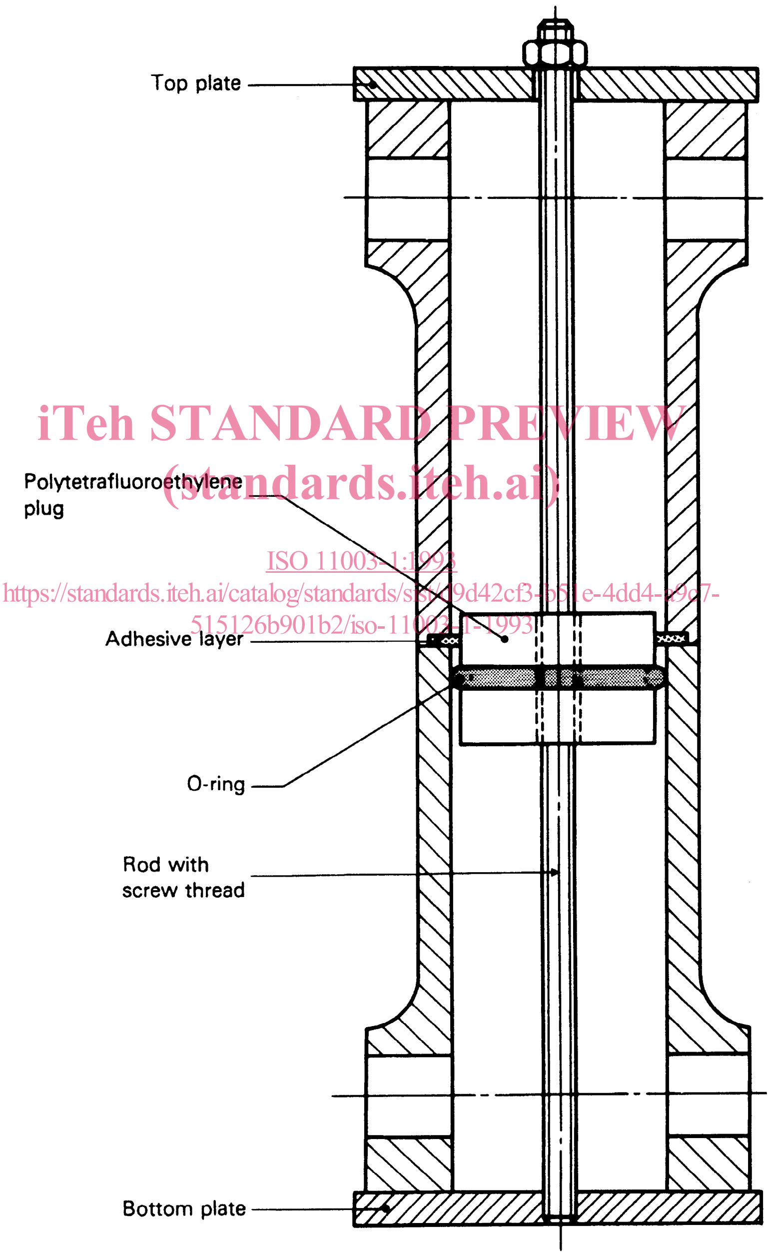
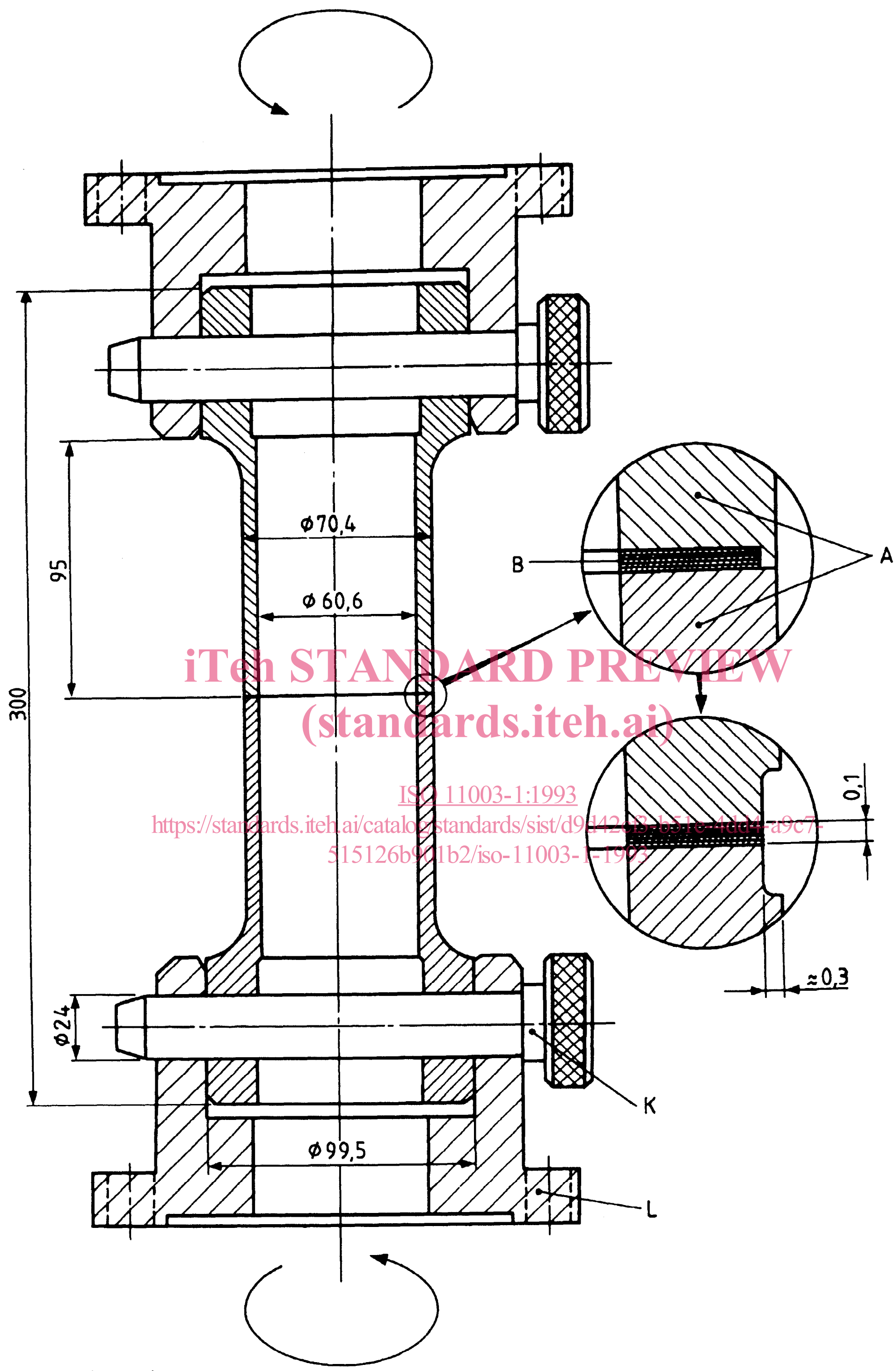


Figure 2 — Coaxially aligned hollow cylinders

Dimensions in millimetres



A Adherends
B Adhesive
K Bolt
L 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 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.

5.5 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.

The width ($r_o - r_i$) of the adhesive 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 5.4 and figure 3).

Table 1 — Recommended specimen sizes

Dimensions in millimetres

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

5.6 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 within ± 1 °C is required.

6.2 Shear rate

The rate of shear $\dot{\gamma}$ of the adhesive shall range from 0,005 s^{-1} to 0,02 s^{-1}.

NOTE 1 The preferred rate of shear $\dot{\gamma}$ of the adhesive 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 adhesive bond thickness, in millimetres;

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

7 Procedure

Fix the specimens, for example by two bolts, in the testing apparatus, equipped with a temperature cabinet if required. By proper adjustment, the joint shall be exempt from any load.

Record the initial portion of the torque displacement curve, up to a strain γ of 0,06, three times at high resolution in order to determine the shear modulus. Subsequently, increase the torque up to failure of the joint and record a complete torque displacement curve at a suitable amplification setting.

Check the surfaces of the bonded parts after failure and reject any specimens with incompletely filled adhesive bonds (due e.g. to the presence of bubbles or voids).

8 Expression of results

8.1 The shear stress τ, expressed in megapascals, in the bond line close to the outer rim 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, in newton-millimetres, acting across the joint;

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

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

8.2 The displacement V_M measured during the test is composed of the displacement V_A of the adhesive and the displacement V_T due to the twist of the two adherends (see figure 4). Therefore, the shear strain, γ, in a bond of thickness d is given by the equation:

$$\gamma = \tan \alpha = \frac{V_A}{d} = \frac{V_M - V_T}{d}$$

where

V_A, V_M, V_T and d are measured in millimetres;

α is the angle of deformation of the adhesive layer.

V_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 V_T is determined experimentally at the appropriate temperatures for an unbonded specimen made of the same material and having the same dimensions.

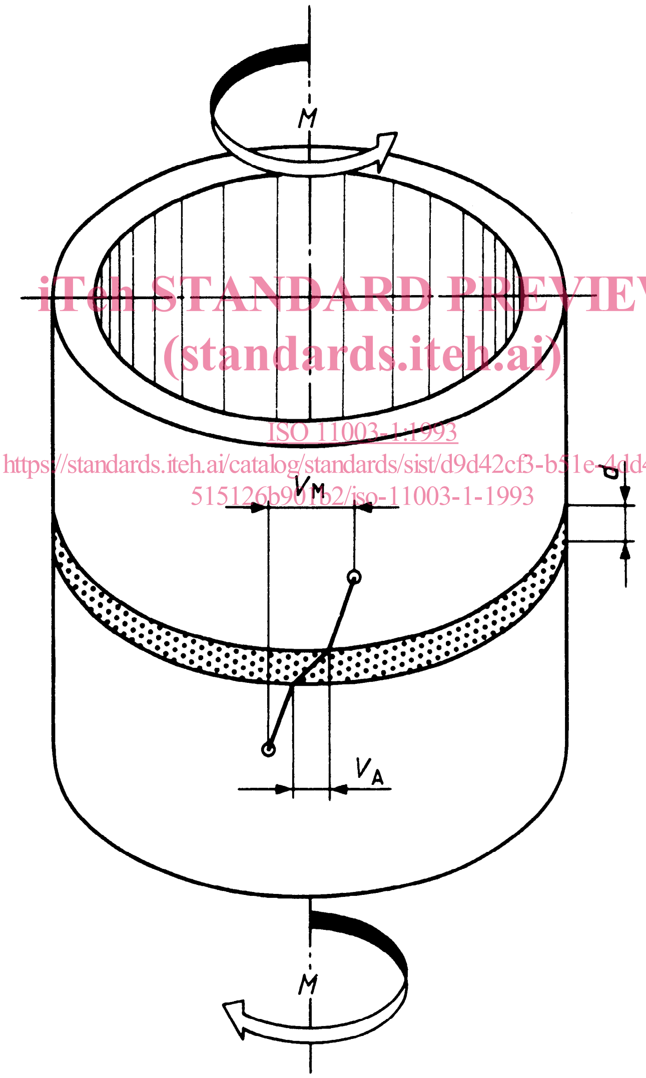


Figure 4 — Scheme of the displacements on the surface of the bonded cylinders

8.3 The shear modulus $G_A = \tau/\gamma$ of the adhesive is determined from the slopes of the initial portions of the three stress-strain curves. A linear zone at low strain indicates elastic behaviour of the joint. A curved zone is observed if the polymer in the joint demonstrates viscoelastic behaviour.

8.4 Calculate the arithmetic mean of the results and the standard deviation for the shear modulus, shear stress at failure (shear strength) and shear strain at 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 time of revision.

10 Test report

The test report shall include the following items:

a) reference to this part of ISO 11003;

b) all the information necessary for complete identification of the adhesive tested;

c) identification of the material of which the adherends are made;

d) type of specimen A, B or C (give inner and outer diameters if different from the recommended sizes);

e) detailed information on all methods of surface preparation used;

f) description of the bonding method, including the bonding temperature and pressure, the adhesive curing time and information on the conditioning of the specimens;

g) thickness of the adhesive layer;

h) test temperature;

i) number of specimens;

j) individual results of shear, modulus, shear stress at failure and shear strain at failure;

k) ranges of torque and displacement used;

l) averaged results, including standard deviation;

m) diagram of shear stress versus shear strain;

n) observations concerning the debonded surfaces, in accordance with ISO 10365;

o) any deviation from the specified procedure which may have influenced the results.