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Fibre-reinforced plastic composites — Shear test method using a shear frame for the determination of the in-plane shear stress/shear strain response and shear modulus

Composites plastiques renforcés de fibres — Méthode d'essai de cisaillement à l'aide d'un châssis de cisaillement pour la détermination de la contrainte de cisaillement /déformation au cisaillement dans le plan et du module de cisaillement

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Foreword

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For an explanation on 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 the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 13, *Composites and reinforcement fibres*.

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.

Introduction

The test method described in this document uses a shear frame fixture in order to introduce a pure shear loading throughout the free area of the test specimens. The edges of the test specimens are uniformly clamped during the test procedure avoiding fibre rotation and load re-distribution effects. This allows for the ultimate shear strength of high shear-elongation materials to be obtained even at shear strains higher than 5 % which is a limitation when using ISO 14129 or other standards regarding in-plane shear test methods for fibre reinforced plastic composites.

Fibre-reinforced plastic composites — Shear test method using a shear frame for the determination of the in-plane shear stress/shear strain response and shear modulus

1 Scope

This document specifies a method using a shear test apparatus for measuring the in-plane shear stress/shear strain response, shear modulus and shear strength of continuous-fibre-reinforced plastic composite materials with fibre orientations of 0° and 0°/90°.

This method is applicable to thermoset and thermoplastic matrix laminates made from unidirectional layers/non-woven fabrics and/or fabrics including unidirectional fabrics, with the fibres oriented at 0° and 0°/90° to the specimen axis, where the lay-up is symmetrical and balanced about the specimen mid-plane.

The method is suitable for determining shear properties in both the linear and nonlinear load-deformation range even at shear strains greater than 5 %.

Short and long fibre-reinforced plastic composites can also be tested using this document.

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 291, *Plastics — Standard atmospheres for conditioning and testing*

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

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

ISO 2602, *Statistical interpretation of test results — Estimation of the mean — Confidence interval*

ISO 7500-1, *Metallic materials — Calibration and verification of static uniaxial testing machines — Part 1: Tension/compression testing machines — Calibration and verification of the force-measuring system*

ISO 12781-1, *Geometrical product specifications (GPS) — Flatness — Part 1: Vocabulary and parameters of flatness*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
plane
plane spanned by coordinate axes 1 and 2

Note 1 to entry: See Figure 2.

3.2
in-plane shear stress
τ_{12}
stress obtained by dividing the instantaneous tensile load acting on the shear frame by the specimen cross-sectional area

Note 1 to entry: See also 8.1.

Note 2 to entry: The in-plane shear stress is expressed in MPa.

3.3
in-plane shear strength
τ_{12M}
maximum value for the shear stress

Note 1 to entry: See also 8.2.

Note 2 to entry: The in-plane shear strength is expressed in MPa.

3.4
shear strain
γ_{12}
sum of the individual components of the total shear strain of the test specimen

Note 1 to entry: See also 8.3.

3.5
in-plane shear modulus
in-plane chord modulus
G_{12}
shear stress difference τ''_{12} and τ'_{12} divided by the corresponding shear strain difference $\gamma''_{12} = 0{,}005$ and $\gamma'_{12} = 0{,}001$

Note 1 to entry: See also 8.4 and Figure 4.

Note 2 to entry: The in-plane shear modulus is expressed in MPa.

3.6
direction of coordinate axis 1
<test specimen> direction parallel to the loading axis of the test machine

Note 1 to entry: The fibres oriented at an angle of 0° are in this direction.

Note 2 to entry: See Figure 2 and Figure 3.

3.7
direction of coordinate axis 2
<test specimen> direction orthogonal to the loading axis of the test machine

Note 1 to entry: The fibres oriented at an angle of 90° are in this direction.

Note 2 to entry: See Figure 2 and Figure 3.

4 Principle

A square test specimen with recessed corners and reinforcing fibres oriented at 0° and 0°/90° to the specimen axis is held in a shear frame and subjected to pure shear loading. In order to determine the shear modulus and the shear strength, the tensile load acting on the shear frame and the associated shear strain are measured.

In this method, a test specimen is put in a state of pure shear, thus enabling testing to be carried out without interference by superimposed shear and other stresses, and, as a consequence, ensuring that the material characteristics are determined in a reproducible manner.

The test specimen is gripped along all its sides by a device exerting uniform, reproducible pressure and that is equipped with a follower mechanism enabling a constant gripping force to be maintained. The test specimens have no free edges, and therefore there are no load re-distribution effects which might otherwise affect the test results. Because the maximum shear stress occurs in the central portion of the test specimen, no invalid test results owing to material failure of the specimen at the edges where it is gripped are obtained.

5 Test apparatus

5.1 Tensile test machine

5.1.1 General

The tensile test machine shall comply with ISO 7500-1 and meet the specifications given in 5.1.2 and 5.1.3.

5.1.2 Test speeds

The testing machine shall be capable of maintaining the test speeds as specified in Table 1.

Table 1 — Recommended test speeds

Test speed *v* mm/min	**Tolerance** %
0,125	±20
0,25	
0,5	
1	
2	
4	
10	
20	±10
50	
100	
200	
300	
500	

5.1.3 Force indicator

The force measurement system shall comply with class 1 as defined in ISO 7500-1.

5.2 Shear frame

The specimen is placed inside two identical halves of a shear frame and is held in place by means of a clamping device which controls the grip on the specimen in its plane along all its sides and ensures that this clamping force is applied to the specimen in a uniform and reproducible manner throughout the test. The kinematic principle of the shear frame, deforming the square test specimen into a rhombic specimen when an axial force is applied, is shown in Figure 1.

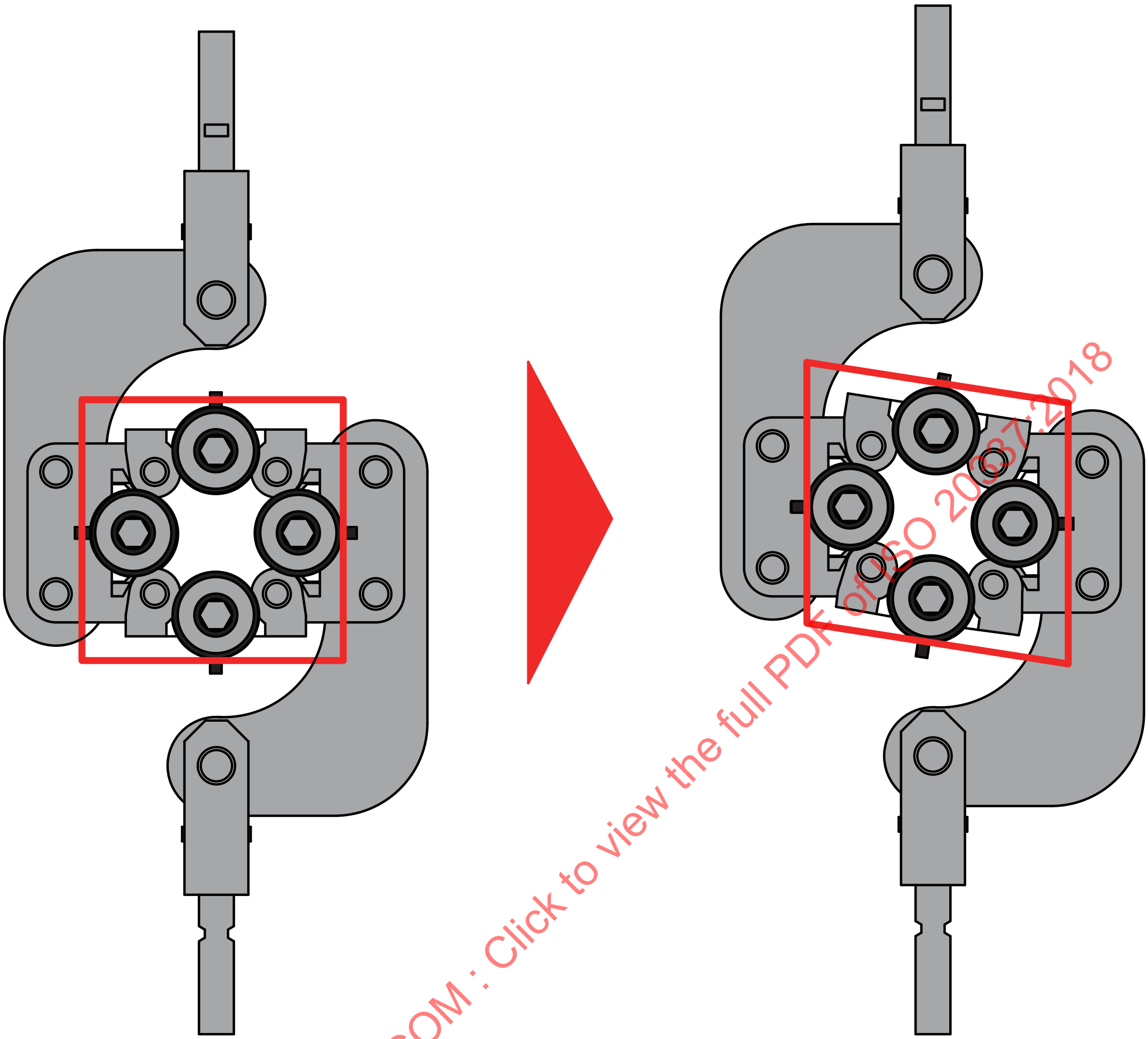
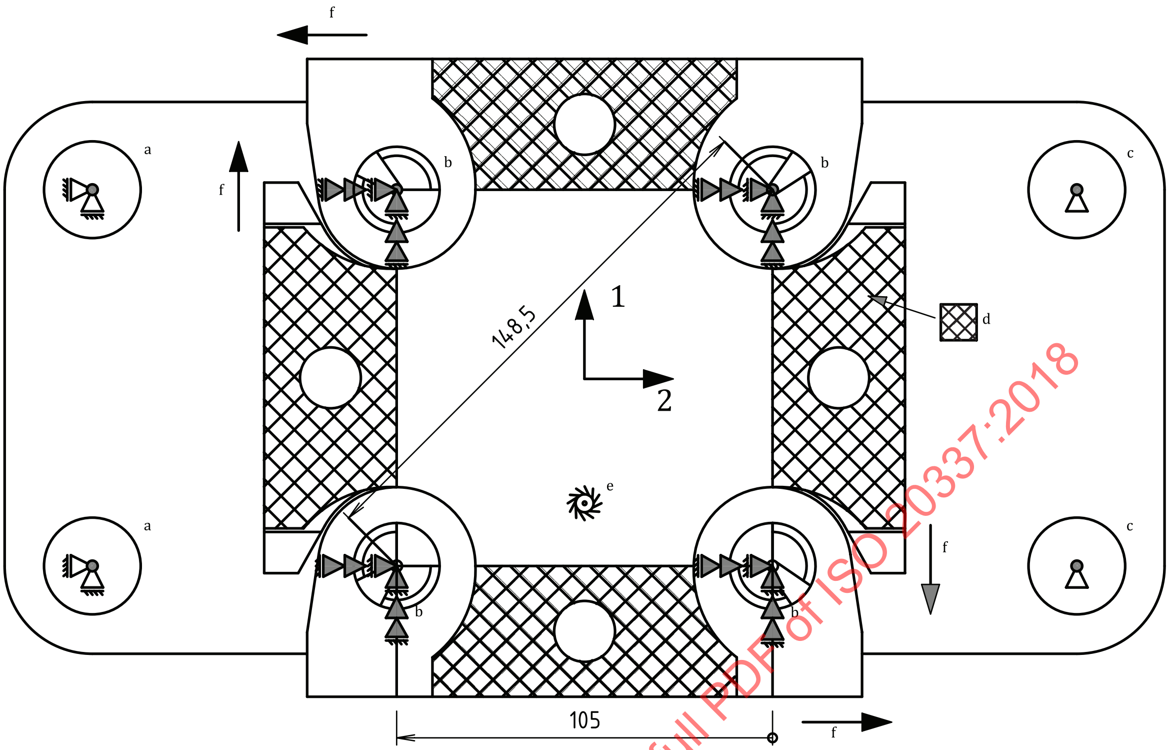


Figure 1 — Kinematic principle of the shear frame

A detailed description of the boundary conditions of one half of the shear frame is presented in Figure 2. As the maximum shear stress mainly occurs in the centre of the specimen, a premature failure of the specimen in the clamping region is avoided.

Dimensions in millimetres



Key

1 direction of coordinate axis 1

2 direction of coordinate axis 2

a Support.

b Movement.

c Load introduction.

d Pressure from grip.

e Displacement hindered by symmetry.

f Force.

▪ hinge joint

 specified translation

 hindered translation

 coupled translation

 coupled translation

 pressure

Figure 2 — Boundary conditions of one half of the shear frame

5.3 Strain measurement

The procedure requires measurement of the strain at an angle of 45° to the coordinate axes (see Figure 3).

When using strain gauges, these shall be placed on the front and rear faces of the test specimen in order to measure positive strains. The size and properties of the gauges shall be selected on the basis of the specimen used. Strain gauges that line up as shown in Figure 3 shall be accurate to ±1 % of the full scale. Gauges, surface preparation and bonding agents shall be chosen to give adequate performance on the materials under test, and suitable strain-recording equipment shall be used.

When using an optical 3-D measurement system, it is sufficient to measure the strain on one side of the specimen. The strain shall be measured to suit the arrangement of the strain gauge (see Figure 3). Out-of-plane deflection shall be measured before testing by use of strain gauges recorded on the two faces of the specimen to verify the condition in Formula (1).

5.4 Micrometer

A micrometer or equivalent measuring device with a maximum permitted measurement error of ≤0,01 mm shall be used to measure the test specimen thickness, *h*.

The micrometer shall have contact faces appropriate to the surface being measured (i.e. flat faces for plane, polished surfaces and hemispherical faces for irregular surfaces).

See ISO 16012 where applicable.

6 Test specimens

6.1 Shape and dimensions

Figure 3 shows the test specimen geometry regarding the fibre orientation as well as its clamped and free area. The test specimen shall be (165 ± 0,5) mm wide and (165 ± 0,5) mm long. The shear area that is decisive for the shear test shall be at least (105 ± 0,5) mm wide and (105 ± 0,5) mm long. The flatness of the test specimen shall be at least ≤1 mm as defined in ISO 12781-1. Unless otherwise specified, the thickness of the test specimen shall be (4 ± 0,1) mm. The thickness of the specimen shall be selected so as to prevent its out-of-plane deflection. Deflection is permitted if, up to failure, the difference between the shear strain recorded on the two faces of the specimen during the shear test satisfies Formula (1):

$$\left|\frac{\varepsilon_{\mathrm{v}} - \varepsilon_{\mathrm{h}}}{\varepsilon_{\mathrm{v}} + \varepsilon_{\mathrm{h}}}\right| \le 0{,}1 \qquad (1)$$

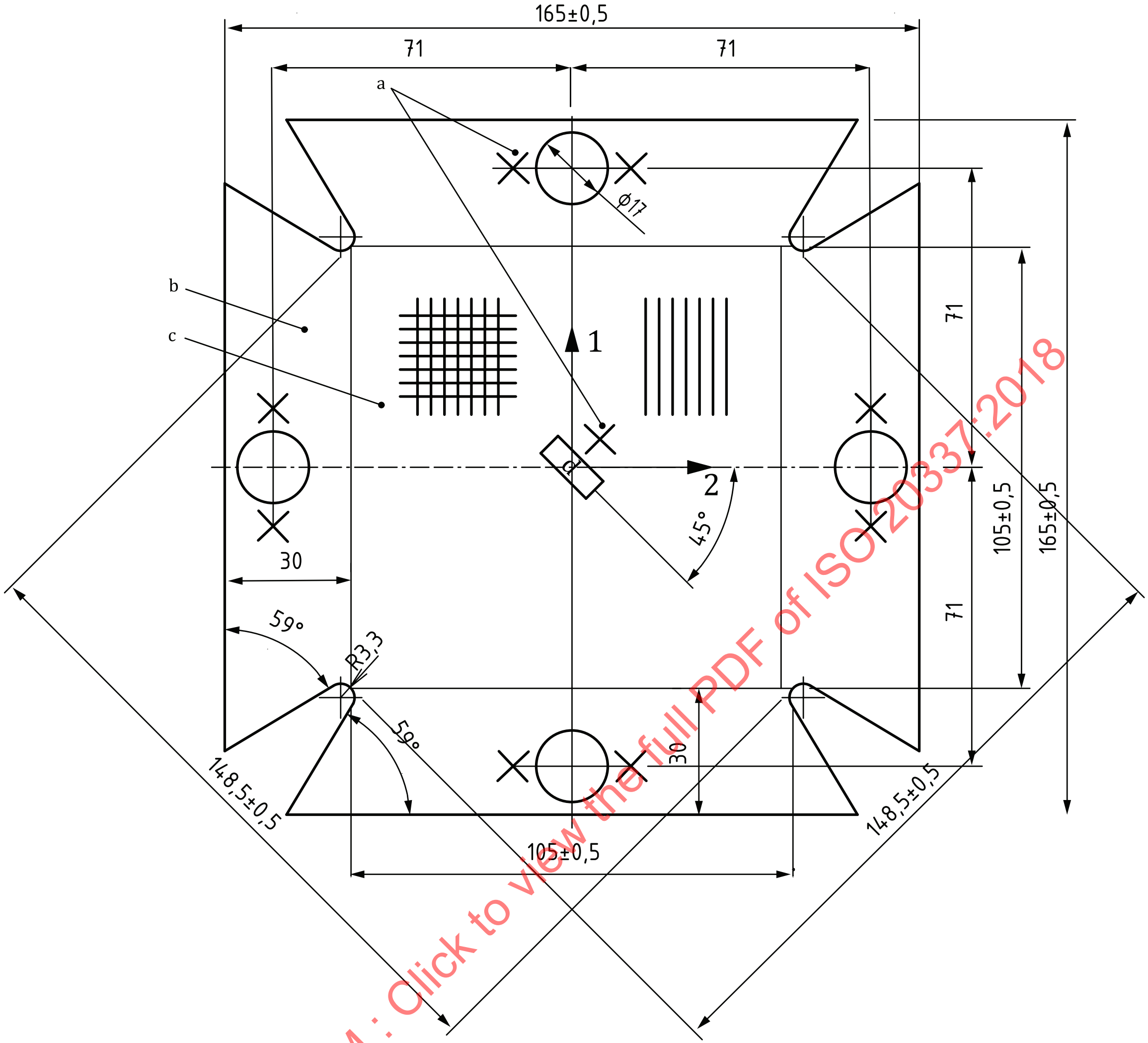
where

ε_{v} is the strain on the front face of the specimen;

ε_{h} is the strain on the rear face of the specimen.

The size of the free shear area, as shown in Figure 3, shall be checked by means of the diagonal dimension which shall be (148,5 ± 0,5) mm.

Dimensions in millimetres



Key

1 direction of coordinate axis 1

2 direction of coordinate axis 2

a Position for thickness measurement.

b Area covered by grip.

c Free shear area.

d Strain measurement.

Figure 3 — Test specimen geometry showing the fibre axes

6.2 Preparation of test specimens

A panel with the specified balanced and symmetrical fibre orientation of 0° and 0°/90° to the specimen axis shall be prepared in accordance with ISO 1268 or another specified/agreed procedure.

Individual test specimens or series of test specimens shall be cut to the required size. Some parameters for machining are specified in ISO 2818.

When testing specimens with fibre orientation only at 0°, the specimen shall be placed in the shear frame with the fibres oriented parallel to the loading axis of the test machine as shown in Figure 3.

6.3 Inspection of the test specimens

The test specimen surfaces shall be free of scratches, pits, sink marks and flashes. The test specimens shall be free of delaminations, and be flat and free of twist. These characteristics shall be checked visually using straight-edges, squares and flat plates, and by measuring with micrometer callipers. Test specimens showing measurable or observable departures from one or more of these characteristics shall be rejected or machined to the required size and shape before testing.

6.4 Number of test specimens

6.4.1 At least five test specimens shall be tested.

6.4.2 The results from test specimens that rupture at or inside the grips (i.e. failure due to clamping) shall be rejected and new specimens shall be tested.

6.5 Conditioning of test specimens

Where applicable, the test specimens shall be conditioned as specified in the international product standards for the material under test. In the absence of such information, the most appropriate conditions from ISO 291 shall be selected unless agreed otherwise by the interested parties.

7 Procedure

7.1 Test atmosphere

Where applicable, the test specimens shall be tested as specified in the international product standards for the material under test. In the absence of such information, the most appropriate conditions from ISO 291 shall be selected unless agreed otherwise by the interested parties (e.g. for testing at higher or lower temperatures).

7.2 Determination of the test specimen thickness

The thickness of the test specimen shall be measured to the nearest 0,02 mm at the positions in the area covered by the grips – a total of 8 positions per test specimen – as shown in Figure 3. The mean value shall be determined and used for the subsequent calculations.

If possible, the thickness of the specimen in the vicinity of the strain gauge should also be measured.

7.3 Test speed

Where applicable, the test speed shall be set to conform to the international product standard for the material under test. When this information is not available, the test speed shall be v = 4 mm/min.

7.4 Data collection

The tensile load and the corresponding strain ε_v (on the front face of the test specimen) and ε_h (on the rear face of the specimen) shall be recorded throughout the test. When using an optical 3-D measurement system, the strain on the front face of the specimen shall to be recorded.

7.5 Test termination

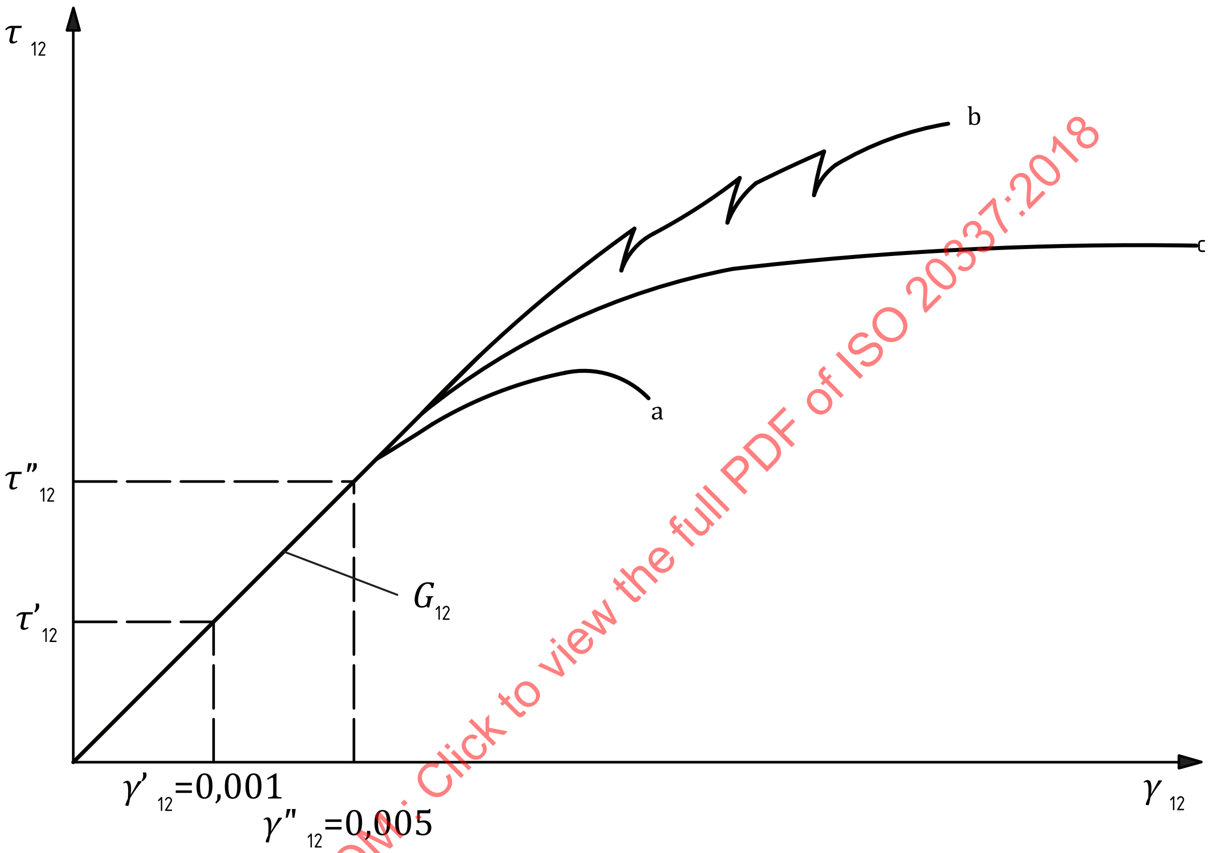
The test is terminated when any one of the three following failure modes has been met (see Figure 4).

a) The force diagram shows a global maximum. The corresponding shear stress is defined as being the shear strength.

b) Interfibre failure occur. After this, it is no longer possible to transmit a defined force into the specimen. The shear stress at the time of the first break between fibres occurs is defined as being the shear strength.

c) The test shall be completed at a maximum strain of 20 % if ultimate does not occur.

NOTE Due to large deformations, if 20 % shear strain is exceeded, the nonlinear or second-order terms of the strain tensor cannot be neglected.



Key

τ_{12} shear stress

γ_{12} shear strain

G_{12} plane shear modulus (or chord modulus)

a Global maximum.

b Interfibre failure.

c 20 % shear strain.

Figure 4 — Shear stress/shear strain diagram

7.6 Failure mode

The failure mode shall be checked and recorded (see also 7.5).

8 Calculation and expression of results

8.1 The in-plane shear stress τ_{12}, expressed in MPa, shall be calculated using Formula (2):

$$\tau_{12} = \frac{F}{bh} \quad (2)$$

where

F is the instantaneous load, in N;

b is the shear area width, in mm;

h is the test specimen thickness, in mm.

NOTE When using the standard specimen shown in Figure 3, the shear area width amounts 105 mm.

8.2 The in-plane shear strength τ_{12M}, expressed in MPa, shall be calculated using Formula (3):

$$\tau_{12M} = \frac{F_m}{bh} \quad (3)$$

where F_m is the load at which the test terminates as defined in 7.5, in N.

8.3 The shear strain, γ, shall be calculated using Formula (3):

$$\gamma = |\varepsilon_v| + |\varepsilon_h| \quad (4)$$

$|\varepsilon_v|$ shall be applied to take shear deformation into account when using an optical measuring system.

8.4 The in-plane shear modulus (chord modulus), G_{12}, expressed in MPa (see Figure 4), shall be calculated using Formula (5):

$$G_{12} = 1{,}1 \frac{\tau''_{12} - \tau'_{12}}{\gamma''_{12} - \gamma'_{12}} \quad (5)$$

where

τ'_{12} is the shear stress at a shear strain γ'_{12} = 0,001;

τ''_{12} is the shear stress at a shear strain γ''_{12} = 0,005.

As the stresses are not evenly distributed throughout the test specimen, the shear stiffness is corrected by applying a factor of 1,1 (see Reference [5]).When an optical full field strain measurement system is used, which enables to calculate a mean shear strain value, the factor in Formula (5) should be taken as 1,0.

8.5 The arithmetic mean and standard deviation of the individual shear strength and shear modulus values thus determined shall be calculated. If required, the 95 % confidence interval of the mean value is to be determined using the procedure given in ISO 2602.

9 Test report

The test report shall include the following information:

a) a reference to this document, i.e. ISO 20337:2018;

