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Fibre-reinforced plastic composites — Determination of interlaminar strength and modulus by double beam shear test

Composites plastiques renforcés de fibres — Détermination de la résistance interlaminaire et du module par un double essai de cisaillement de faisceau

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Foreword

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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).

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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

Interlaminar shear (ILS) properties of load-bearing composite laminates are important for structural design, stress analysis and numerical modelling, material development and selection, component manufacture as well as for repair of delaminated structural components. A number of test methods have been developed for the determination of shear properties of composite laminates and several have been standardized, including short beam strength (SBS) [ASTM D2344, ISO 14130, EN 2377[1)] and EN 2563[1)]], V-notched beam (known also as Iosipescu shear), ASTM D5379, V-notched rail (ASTM D7078) and notched tension (ASTM D3846, BS 4994) or notched compression (BS 6464).

SBS methods are very popular due to their simplicity in specimen preparation, test operation and cost-effectiveness, though they are used to determine only an apparent ILS strength for QA purposes rather than for use in design. However, a loaded SBS specimen does not have a pure ILS region within its gauge section so it often fails in a number of modes, dependent on, amongst others, type of composite materials, lay-up and specimen thickness. Unacceptable SBS failure modes include flexural failure, local crushing (under central loading roller) and plastic deformation and roller-induced through-thickness shear band.

The DBS method is based on loading a composite beam on double support spans (i.e. between 5 loading points), which generates a stress state that minimises axial bending stresses while promoting interlaminar shear stresses. In DBS tests delamination occurred consistently within one of the pure ILS regions in the specimens, for a range of laminated composite materials or lay-ups.

Comparisons with the SBS ILS strength results indicated that the DBS ILS strengths were 20 % to >30 % higher. In addition, a value of the interlaminar shear modulus can be obtained, providing values of E_{11}, E_{22}, G_{12} and ν_{12} are known or measured separately for the material under test.

1) CEN Aerospace series.

Fibre-reinforced plastic composites — Determination of interlaminar strength and modulus by double beam shear test

1 Scope

This document specifies a procedure for determining the interlaminar strength, and modulus, by double beam shear (DBS) tests of fibre-reinforced plastic composites.

The method is suitable for use with glass or carbon fibre-reinforced plastic composites with thermoset matrices, providing an acceptable interlaminar failure is obtained.

This document only applies to laminate with a symmetrical and balanced lay-up as it avoids bending/twisting or bending/extension coupling deformations (see 6.2). The preferred lay-up is unidirectional, with fibres aligned along the specimen (axial) length.

The suitability of the test for specific lay-ups, matrices and fibres (e.g. natural) are assessed by trial tests to ensure the correct delamination failures are obtained.

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 472, *Plastics — Vocabulary*

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

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

ISO 5893, *Rubber and plastics test equipment — Tensile, flexural and compression types (constant rate of traverse) — Specification*

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 472 and the following 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
critical load
F_{crit}
load at delamination, as defined in 9.5 for acceptable failure modes

Note 1 to entry: See Cases 1-3.

Note 2 to entry: It is expressed in newtons (N).

3.2
interlaminar shear strength
$\tau_{13\ max}$
shear strength calculated from the critical load

Note 1 to entry: See 10.1.

Note 2 to entry: It is expressed in megapascals (MPa).

3.3
interlaminar shear modulus
G_{13}
shear modulus calculated from the slope of the load-displacement curve

Note 1 to entry: See 10.2.

Note 2 to entry: It is expressed in gigapascals (GPa).

3.4
span
L
distance between the outermost support rollers

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

3.5 Specimen coordinate axes

NOTE 1 The direction parallel with the plate longitudinal axis is the "1" direction and the direction perpendicular, is the "2" direction (see ISO 1268-4). The direction “3” is perpendicular to the plate (i.e. the through-thickness direction).

NOTE 2 See Figure 1.

3.5.1
longitudinal tensile modulus
E_{11}
tensile modulus in the specimen longitudinal or 1 direction

Note 1 to entry: It is expressed in gigapascals (GPa).

3.5.2
transverse tensile modulus
E_{22}
tensile modulus in the perpendicular or 2 direction

Note 1 to entry: It is expressed in gigapascals (GPa).

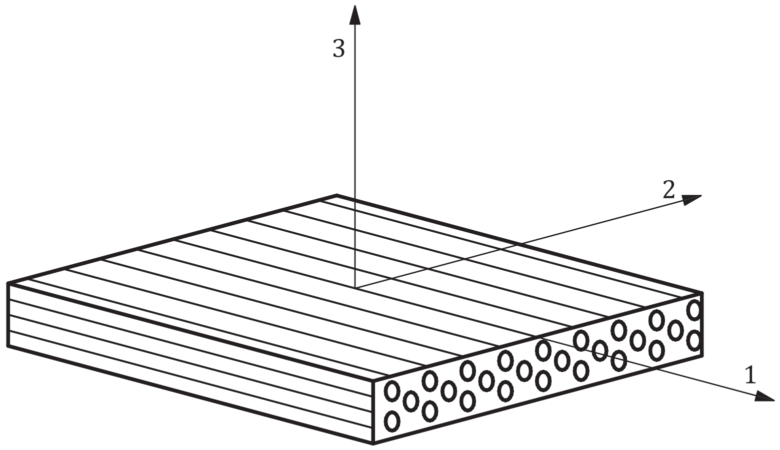
3.5.3
in-plane shear modulus
G_{12}
shear modulus in the 1-2 plane

Note 1 to entry: It is expressed in gigapascals (GPa).

3.5.4
in-plane poisson ratio
ν_{12}
Poisson’s ratio in the 1-2 plane

Note 1 to entry: It is dimensionless.

Note 2 to entry: Properties defined in 3.5.1 to 3.5.4 are required for calculation of the interlaminar shear modulus using either manufacturer's or measured data (see 10.2).



Key

1 direction parallel with the plate longitudinal axis

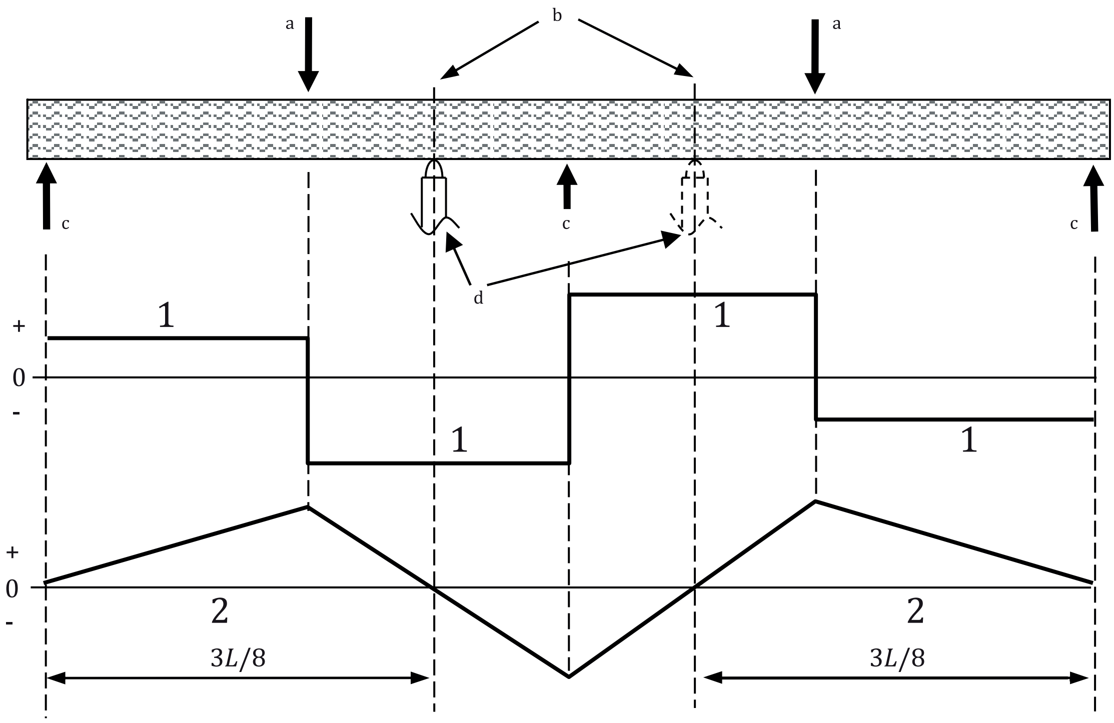
2 direction perpendicular with the plate longitudinal axis

3 direction perpendicular to the plate (i.e. the through-thickness direction, with plies layered perpendicular to this direction)

Figure 1 — Unidirectional reinforced composites plate element showing symmetry axes

4 Principle

A test specimen consisting of a beam of rectangular cross-section is loaded in 5-point flexure, as shown in Figure 2. The applied load generates regions of pure interlaminar shear stress, as indicated in Figure 2. The critical load sustained by the specimen when delamination failure occurs is used to determine the interlaminar shear strength. In addition, the deflection of the specimen under load is used to determine the interlaminar shear modulus. In order to calculate the interlaminar shear modulus, it is necessary to know or measure the following properties: E_{11}, E_{22}, G_{12} and ν_{12}.



Key

1 ILS stress
2 bending stress
a Load.
b Sections of pure shear.
c Support.
d Displacement measurement points.

Figure 2 — Stress distributions in DBS specimen

5 Apparatus

5.1 Test machine

5.1.1 General

The **test machine** conforms to ISO 5893 as appropriate to the requirements given in 5.1.2 to 5.1.3.

5.1.2 Speed of testing, *v*

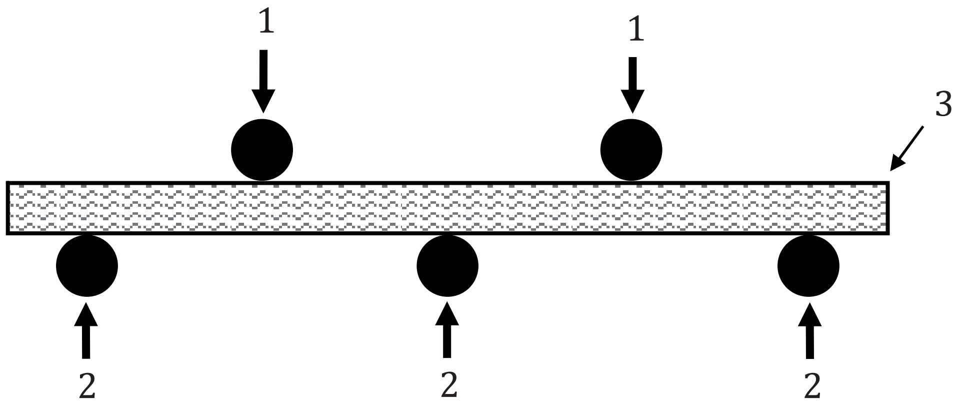
It shall be kept constant according to ISO 5893.

5.1.3 Indicator for load

The error in the indicated force is less than ±1 % of the load to be measured (see Class 1 of ISO 7500-1).

5.2 Micrometer or equivalent, capable of reading to 0,01 mm, or less, and suitable for measuring the thickness, *h* and width, *b* of the test specimen. The micrometer shall have faces appropriate to the surface being measured (i.e. flat faces for flat, polished surfaces and hemispherical faces for irregular surfaces).

5.3 Loading fixture, a 5 point flexure jig with adjustable spans, as shown schematically in Figure 3. The loading/support rollers are uniformly positioned within the span (tolerance ± 0,2 mm), as shown in Figure 4. The loading/support rollers have a contact diameter of 6 mm (tolerance 0 mm to −0,1 mm). A typical set-up is shown in Figure 5.



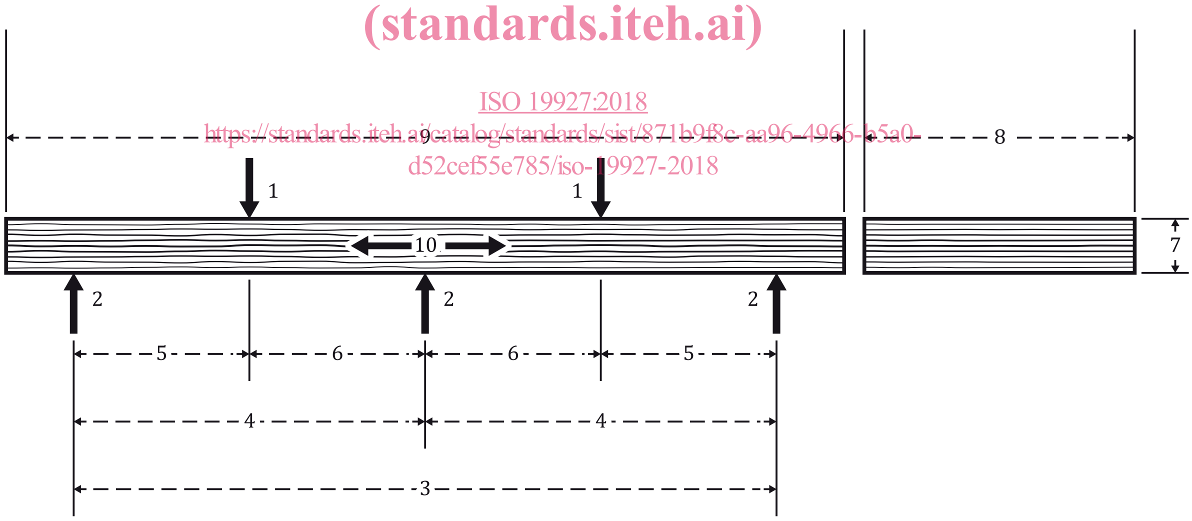
Key

1 loading rollers

2 support rollers

3 specimen

Figure 3 — Schematic of double-beam shear fixture



a) Side elevation **b) End elevation**

Key

1 loading points

2 support points

3 span

4 1/2 span

5 outer region

6 inner region

7 specimen thickness

8 specimen width

9 specimen length

10 Fibre direction (unidirectional specimen)

Figure 4 — Test specimen and rollers lay-out for determination of interlaminar modulus and strength

