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Bamboo structures — Engineered bamboo products — Test methods for determination of mechanical properties using small size specimens

Structures en bambou — Produits en bambou reconstitués — Méthodes d'essai pour la détermination des propriétés mécaniques à partir d'éprouvettes de petites tailles

Reference number
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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 document 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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This document was prepared by Technical Committee ISO/TC *165*, *Timber structures*.

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

Engineered bamboo products are processed bamboo-based composites designed for structural applications, including bamboo scrimber and glued laminated bamboo. For each type of engineered bamboo product, it is necessary to measure mechanical properties. This document is intended to provide manufacturers, regulatory agencies, and end-users with a means to evaluate the mechanical properties of engineered bamboo products intended for structural applications using small size specimens.

This document is an internationally agreed reference standard for the measurement of mechanical properties of engineered bamboo products as defined in 3.1 and 3.2. Other standards related to the measurement of material properties may be deemed to comply with this document, provided that the adjustments necessary to establish equivalency between this and other standards are applied appropriately.

Bamboo structures — Engineered bamboo products — Test methods for determination of mechanical properties using small size specimens

1 Scope

This document specifies test methods, using small size specimens, suitable for determining the following mechanical properties of engineered bamboo products: tensile strength parallel-to-fibre; tensile modulus parallel-to-fibre; compressive strength parallel-to-fibre; tensile strength perpendicular-to-fibre; tensile modulus perpendicular-to-fibre; compressive strength perpendicular-to-fibre; compressive modulus perpendicular-to-fibre; shear strength parallel-to-fibre and shear modulus parallel-to-fibre.

NOTE This document provides an alternative test method to ISO 23478.

This document specifies test procedures for currently manufactured products as defined in 3.1 and 3.2 to evaluate material properties. The methods specified in this document are applicable to small size test specimens. The methods required to determine characteristic values, design values, or allowable values of the mechanical properties for a population are out of the scope of this document. Materials that do not conform to the definitions of bamboo scrimber or glued-laminated bamboo are beyond the scope of this specification.

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 23478, *Bamboo structures — Engineered bamboo products — Test methods for determination of physical and mechanical properties*

ASTM D2915, *Sampling and data-analysis for structural wood and wood-based products*

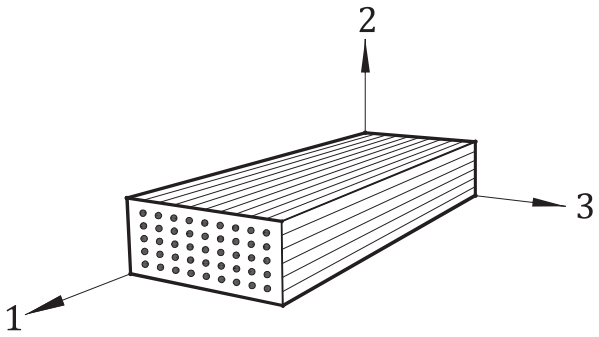
3 Terms and definitions

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

3.1
bamboo scrimber
panel or lumber made of compressed bamboo fibre bundle strips or compressed bamboo fibre bundle sheet which has three mutually perpendicular axes

Note 1 to entry: The three axes are shown in Figure 1.

Note 2 to entry: Bamboo scrimber can be approximately deemed as orthotropic material; hence it has two mutually orthogonal minor axes in the plane perpendicular to the major axis. Unless otherwise stated, the properties of two minor axes can be ideally considered to have same properties because the differences between them are trivial for structural use.

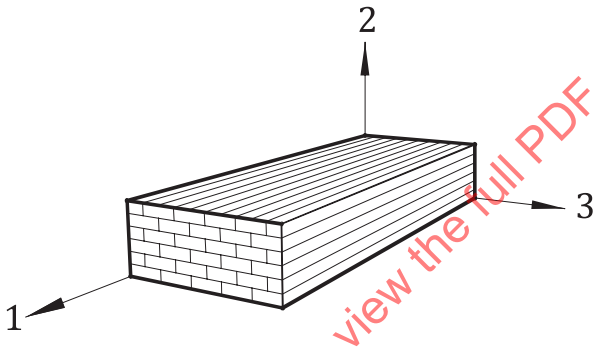


Key

1 along the direction of the bamboo fibres

2, 3 two mutually orthogonal directions in a plane that is perpendicular to axis-1

Figure 1 — Example of bamboo scrimber



Key

1 along the direction of the bamboo fibres

2, 3 two mutually orthogonal directions in a plane that is perpendicular to axis-1

Figure 2 — Example of glued laminated bamboo

3.2
glued laminated bamboo
structural member formed by bonding together bamboo strips with their fibre orientation essentially parallel which has three mutually perpendicular axes

Note 1 to entry: The three axes are shown in Figure 2.

3.3
grade
population of engineered bamboo products with defined design properties

4 Symbols

A_c	area of the cross section of the compressive specimen, in mm^2
b	width of critical section located at the reduced cross section, in mm
d_1	coupon width between notches of the V-notched rail shear test specimen, in mm
E_0	modulus of elasticity parallel to the fibre, in N/mm^2

$E_{c,0}$	modulus of elasticity in compression parallel to the fibre, in N/mm^2
$E_{t,0}$	modulus of elasticity in tension parallel to the fibre, in N/mm^2
Et,90	modulus of elasticity in tension perpendicular to the fibre, in N/mm^2
F	load, in N
$F_{c,0,u}$	compressive load parallel to the fibre at failure, in N
$F_{c,90,u}$	compressive load perpendicular to the fibre at failure, in N
$F_{s,u}$	shear load at failure, in N
$F_{t,0,u}$	tensile load parallel to the fibre at failure, in N
$F_{t,90,u}$	tensile load perpendicular to the fibre at failure, in N
$f_{c,0}$	compressive strength parallel to the fibre, in N/mm^2
$f_{s,0}$	shear strength parallel to the fibre, in N/mm^2
$f_{t,0}$	tensile strength parallel to the fibre, in N/mm^2
$f_{t,90}$	tensile strength perpendicular to the fibre, in N/mm^2
$f_{s,90}$	shear strength perpendicular to the fibre, in N/mm^2
G	shear modulus, in N/mm^2
G_0	shear modulus parallel to the fibre, in N/mm^2
G_{90}	shear modulus perpendicular to the fibre, in N/mm^2
h	overall coupon thickness of the V-notched rail shear test specimen, in mm
t	thickness of critical section located at the reduced cross section, in mm
$\Delta F_{c,0}$	incremental compressive load parallel to the fibre, in N
$\Delta F_{t,0}$	incremental tensile load parallel to the fibre, in N
$\Delta F_{t,90}$	incremental tensile load perpendicular to the fibre, in N
$\Delta F_{s,0}$	incremental shear load parallel to the fibre, in N
$\Delta F_{s,90}$	incremental shear load perpendicular to the fibre, in N
$\Delta\sigma$	incremental stress, in MPa
$\Delta\sigma_{c,0}$	$\Delta\sigma_{c,0} = \Delta F_{c,0} / bt$, incremental compressive stress parallel to the fibre, in MPa
$\Delta\sigma_{t,0}$	$\Delta\sigma_{t,0} = \Delta F_{t,0} / bt$, incremental tensile stress parallel to the fibre, in MPa
$\Delta\sigma_{t,90}$	$\Delta\sigma_{t,90} = \Delta F_{t,90} / bt$, incremental tensile stress perpendicular to the fibre, in MPa
$\Delta\varepsilon$	incremental strain
$\Delta\varepsilon_{c,0}$	incremental compressive strain parallel to the fibre
$\Delta\varepsilon_{t,0}$	incremental tensile stain parallel to the fibre

$\Delta\varepsilon_{t,90}$ incremental tensile stain perpendicular to the fibre

$\Delta\varepsilon_{+45}$ incremental stain over a gauge length at +45 direction

$\Delta\varepsilon_{-45}$ incremental stain over a gauge length at -45 direction

5 Reference population

The population from which the test sample was obtained shall be fully described. The description shall reference all of the attributes that may affect evaluated properties or restrict constituent materials to the grouping. The description shall include but is not limited to:

a) species or species grouping, population boundary;

b) age of the bamboo feedstock when harvested;

c) designation of the product;

d) size or size range of the product;

e) moisture condition of the product;

f) preservative treatment of the product;

j) period in which the product was manufactured.

The reference population shall be a grouping from which a representative sample can be drawn to test specimens to characterize the required properties.

6 Sampling

The sampling shall be appropriate to the purpose of the testing and the nature of the reference population. The sampling method shall be documented. The documentation shall include details of the steps taken to ensure that each of the variants listed in the population as described in Clause 5 is included in the representative sample.

Unless otherwise stated, test specimens shall be selected from random locations within a piece of engineered bamboo product. Specimens cut from pre-defined locations (center of a piece of engineered bamboo product, or a randomly selected end within a piece or a section free of defects or imperfections) may be deemed to comply with this requirement provided this does not produce any bias in measured properties.

Each test specimen for a given size, grade, or property shall be cut from a different piece of engineered bamboo product and more than one type of test specimen may be cut from each piece. Sampling of the test materials shall be done in accordance with applicable sections on Statistical Methodology of ASTM D2915.

Materials with larger assumed or assigned population coefficients of variation, C_V, of the tested properties should have a larger sample size. It is possible to use the expected confidence limit to estimate the sample size based on the expected reduction of the characteristic property calculated from the test data.

7 Conditioning of test specimens

Test specimens shall be conditioned to an equilibrium moisture content resulting from a temperature of (23 ± 3) °C and relative humidity of (65 ± 5) %. A test piece is considered to be conditioned when it attains constant mass. Constant mass is deemed to have been attained when the results of two successive weighings, carried out at intervals of not less than 6 h, do not differ by more than 1 %.

8 Test conditions

Unless otherwise specified in the description of the reference population, the reference moisture content at the time of testing shall be consistent with conditioning at a temperature of 23 °C (±3 °C) and 65 % (±5 %) relative humidity.

At the time of testing, the moisture content, the temperature, and the time-to-failure of the specimen shall be recorded.

If tests results are to be used in the same environmental conditions in which testing took place, or if the laboratory is unable to follow the standard, storage, conditioning, and testing under ambient temperature and relative humidity is permitted. The values of the temperature (±3 °C) and the relative humidity (±5 %) for the laboratory shall be recorded in the test report in addition to the moisture content determined for individual specimens.

9 Density and moisture content

9.1 Density

Measurement of the density of a test specimen shall be in accordance with the method specified in ISO 23478.

9.2 Moisture content

Measurement of moisture content of a test specimen shall be in accordance with the method specified in ISO 23478.

10 Measurement of mechanical properties

Mechanical properties shall be determined via tests by using small size specimens. Table 1 lists the mechanical properties covered by this standard.

Table 1 — Mechanical properties covered by this document

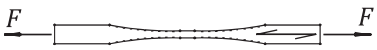
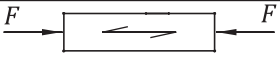
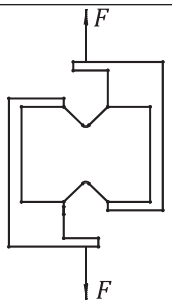
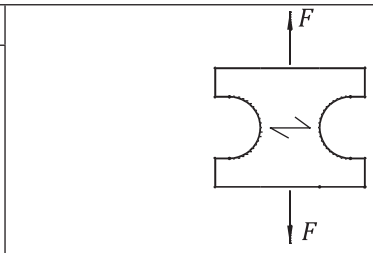
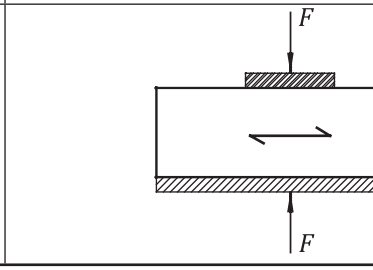
Tensile strength parallel-to-fibre		10.1
Tensile modulus parallel-to-fibre		10.1
Compressive strength parallel-to-fibre		10.2
Shear strength parallel-to-fibre		10.3
Shear modulus parallel-to-fibre		10.3

Table 1 *(continued)*

Tensile strength perpendicular-to-fibre		10.4
Tensile modulus perpendicular-to-fibre		10.4
Compressive strength perpendicular-to-fibre		10.5

10.1 Tensile properties parallel-to-fibre

10.1.1 Preparation of test specimens

The dimensions of the tension test specimen for the parallel-to-fibre properties shall be as shown in Figure 3. The specimen shall be oriented in such a way that the primary fibre direction of the bamboo (axis 1) is parallel to the direction of the applied load.

Dimensions in millimetres

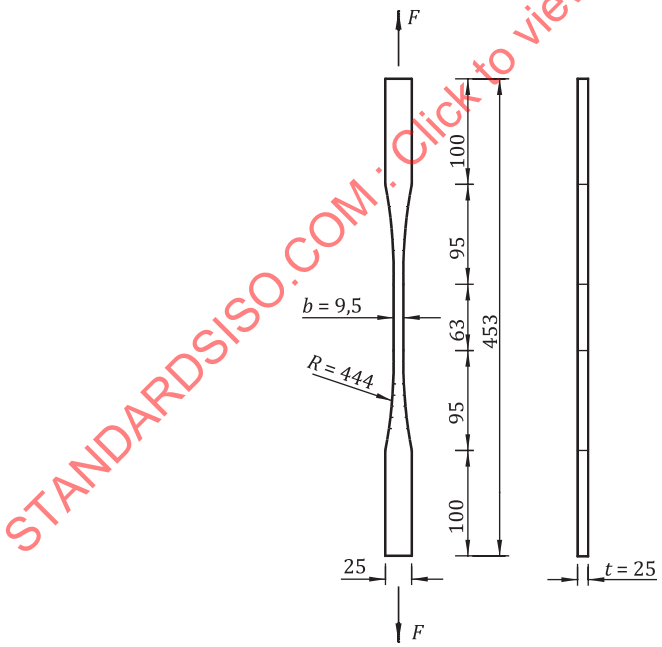


Figure 3 — Parallel-to-fibre tensile test specimen schematic

10.1.2 Test procedure

Fasten the specimen in grips. If required, tensile strain at the middle of the specimen shall be measured using an external clip gauge or adhesively applied electrical resistance strain gauge.

Load shall be applied at a constant rate and the test should be completed within approximately 300 s but not less than 180 s.

The failure mode and corresponding calculated value for derived properties of each tested specimen, regardless of failure mode, shall be reported.

NOTE Possible failure modes in the parallel-to-fibre tension test of GLB are described in A1.

10.1.3 Expression of results

The tensile strength $f_{t,0}$ shall be calculated from Formula (1)

$$f_{t,0} = \frac{F_{t,0,u}}{bt} \tag{1}$$

where, $F_{t,0,u,}$ is the applied load at failure and b and t are width and thickness of critical section located at the reduced cross section (see Figure 3).

When required, the tensile modulus of elasticity parallel to the fibre, $E_{t,0}$, shall be calculated from Formula (2)

$$E_{t,0} = \frac{F_{40} - F_{10}}{bt(\varepsilon_{40} - \varepsilon_{10})} \tag{2}$$

where F_{40} and F_{10} are the applied loads at 40 % and 10 % of $F_{t,0,u}$, respectively, and ε_{40} and ε_{10} are the measured strains at 40 % and 10 % of $F_{t,0,u}$, respectively.

10.2 Compressive properties parallel-to-fibre

10.2.1 Preparation of test specimens

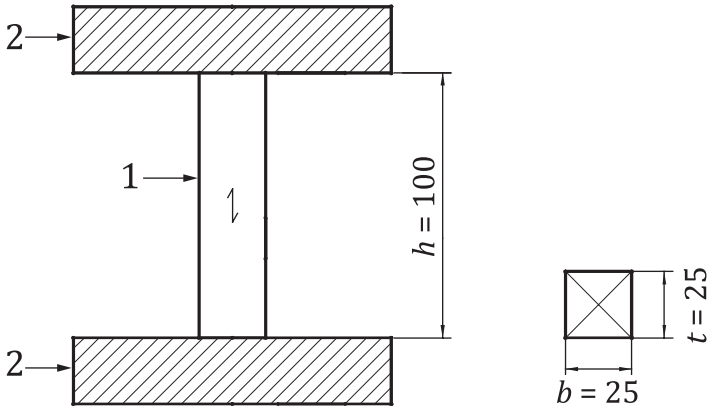
The dimensions of the test specimens used in the measurement of compressive strength parallel-to-fibre shall be 25 mm × 25 mm × 100 mm. Test setup shall be as shown in Figure 4. The specimen shall be oriented in such a way that the primary fibre direction of the bamboo (axis 1) is parallel to the direction of the applied load.

10.2.2 Test procedure

Place the specimen on the test platen and operate the upper crosshead to apply the compression load parallel to the fibre, as shown in Figure 4. If required, compressive strain over a central gage length not exceeding 50 mm of the specimen height shall be measured.

Load shall be applied at a constant rate and the test should be completed within approximately 300 s but not less than 180 s.

Dimensions in millimetres



Key

1 specimen

2 fixtures

NOTE ⇀↽ indicates parallel to fibre orientation

Figure 4 — Parallel-to-fibre compressive test specimen schematic

10.2.3 Expression of results

The compressive strength $f_{c,0}$ shall be calculated from Formula (3)

$$f_{c,0} = \frac{F_{c,0,u}}{bt} \tag{3}$$

where, $F_{c,0,u}$ is the applied load at failure and b and t are width and thickness of the specimen.

When required, the modulus of elasticity parallel-to-fibre (axis-1), $E_{C,0}$, shall be calculated from Formula (4)

$$E_{c,0} = \frac{F_{40} - F_{10}}{bt(\varepsilon_{40} - \varepsilon_{10})} \tag{4}$$

where F_{40} and F_{10} are the applied loads at 40 % and 10 % of $F_{c,0,u}$, respectively, and ε_{40} and ε_{10} are the measured strains at 40 % and 10 % of $F_{c,0,u}$, respectively.

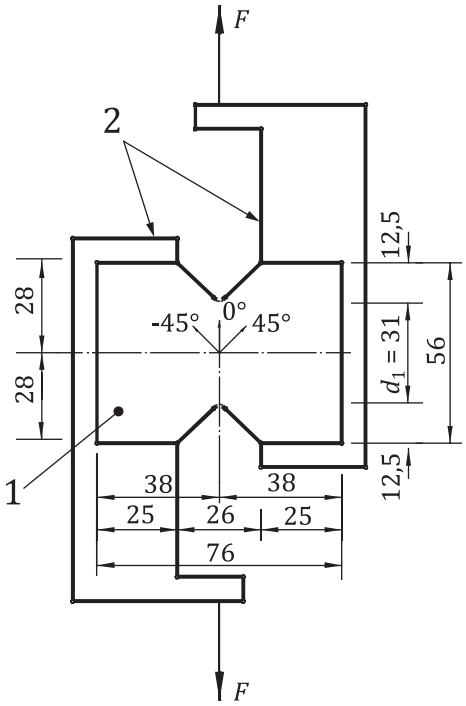
10.3 Shear strength and modulus

10.3.1 Preparation of test specimens

V-Notched rail shear test specimen shall be used to measure the shear strength and shear modulus perpendicular (planes 1-2 and 1-3) of engineered bamboo products. The configuration of the test specimen shall be as shown in Figure 5. The test specimen shall be oriented in such a way that the shear force at the V-notch is appropriate to measure the shear properties of the desired plane.

If it is required to determine the shear modulus, two electrical resistance strain gages with a gage length of 10 mm are oriented at ±45° orientation in the middle of the specimen as shown in Figure 5.

Dimensions in millimetres



Key

1 specimen
2 fixture halves
[a] As required.

Figure 5 — V-Notched rail shear test specimen schematic

10.3.2 Test procedure

Fasten the specimen into suitable grips.

NOTE A.4 provides an apparatus suitable for the conduct of this test.

Load shall be applied at a constant rate and the test should be completed within approximately 300 s but not less than 180 s.

The specimen orientation relative to the engineered bamboo product, failure mode, and corresponding calculated value for derived properties of each tested specimen, regardless of failure mode, shall be reported.

NOTE Possible failure modes in the shear test of GLB are described in A.2.

10.3.3 Expression of results

It is assumed that the shear stress is uniformly distributed over the shearing plane between the two notches. Shear strength parallel-to-fibre $f_{s,0}$ and shear strength perpendicular-to-fibre $f_{s,90}$ shall be calculated from Formula (5):

$$f_{s,0} = \frac{F_{s,u}}{d_1 h} \text{ or } f_{s,90} = \frac{F_{s,u}}{d_1 h} \quad (5)$$

where, $F_{s,u}$ is the value of the applied load at failure; d_1 is the coupon width between notches; h is the overall coupon thickness.

The shear modulus parallel-to-fibre and perpendicular-to-fibre shall be calculated from Formulae (6) and (7) respectively:

$$G_0 = \frac{\Delta F_{s,0}}{d_1 h(|\Delta\varepsilon_{+45}|+|\Delta\varepsilon_{-45}|)} \tag{6}$$

$$G_{90} = \frac{\Delta F_{s,90}}{d_1 h(|\Delta\varepsilon_{+45}|+|\Delta\varepsilon_{-45}|)} \tag{7}$$

where, $\Delta F_{s,0}$ and $\Delta F_{s,90}$ are incremental applied loads parallel-to-fibre and perpendicular-to-fibre, respectively; d_1 is the coupon width between notches; h is the overall coupon thickness; $\Delta\varepsilon_{+45}$ and $\Delta\varepsilon_{-45}$ are incremental strains at +45° and -45° directions, respectively. The incremental loads shall be selected from the linear elastic part of the load-displacement response graph in the range of 10 % to 40 % of the maximum load.

Twisting may occur due to an out-of-tolerance fixture, an out-of-tolerance specimen, or a specimen that is improperly installed in the fixture. It is recommended that at least one specimen of each sample be tested with back-to-back two-element strain gauges to evaluate the degree of twist. Evaluate the percent twist for the specimen by substituting the shear modulus from each side, G_a and G_b into $|(G_a - G_b)/(G_a - G_b)|\times 100$, evaluated at 0,004 engineering shear strain. If the amount of twist is greater than 3 %, the specimen should be examined for the cause of the twisting, and the apparatus or specimen corrected if possible. If no cause is apparent or no correction is possible and the twisting persists, the shear modulus measurement should be made using the average response of back-to-back two-element strain gauges.

10.4 Tension properties perpendicular-to-fibre

10.4.1 Preparation of test specimens

The configuration of the specimen for tension perpendicular-to-fibre shall be as shown in Figure 6. The specimen shall be oriented so that the primary fibre direction (axis 1) is perpendicular to the applied load.

NOTE If the engineered bamboo product from which the specimen is extracted is not large enough, a dimension *d* less than 50 mm can be used.

For GLB, the perpendicular-to-fibre tensile test shall be conducted in the flatwise orientation. To the extent possible, the glueline shall be located away from the minimum cross section.

Dimensions in millimetres

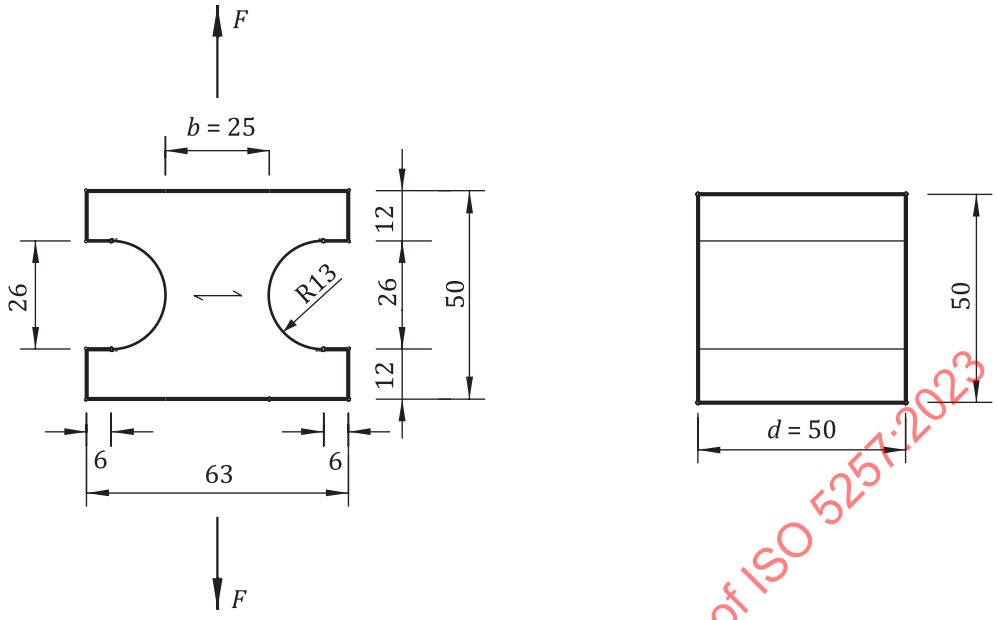


Figure 6 — Perpendicular-to-fibre tensile test specimen schematic

10.4.2 Test procedures

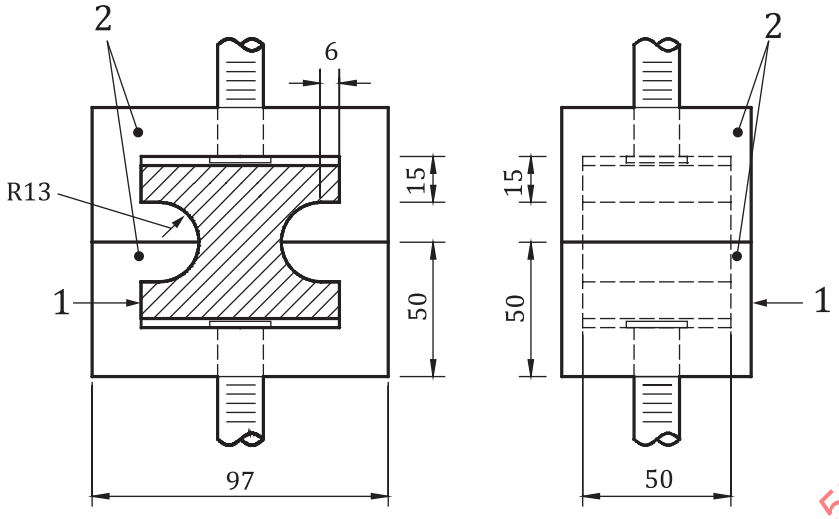
Fasten the specimen in grips as shown in Figure 7. Tensile strain at the middle of the specimen shall be measured.

Load shall be applied at a constant rate and the test should be completed within approximately 300 s but not less than 180 s.

The failure mode and corresponding calculated value for derived properties of each tested specimen, regardless of failure mode, shall be reported.

NOTE Possible failure modes in the perpendicular-to-fibre tension test of GLB are described in A.3.

Dimensions in millimetres



Key

1 specimen
2 fixture halves

Figure 7 — Perpendicular-to-fibre tension test set-up

10.4.3 Expression of results

The tensile strength $f_{t,90}$ shall be calculated from Formula (8)

$$f_{t,\,90} = \frac{F_{t,90,u}}{bd} \tag{8}$$

where, $F_{t,90,u}$ is the value of the applied load at failure; b and d are the width of the critical section and the thickness of test sample.

The modulus of elasticity perpendicular to the fibre, $E_{t,90}$, shall be calculated from Formula (9)

$$E_{t,90} = \frac{F_{40} - F_{10}}{bt(\varepsilon_{40} - \varepsilon_{10})} \tag{9}$$

where F_{40} and F_{10} are the applied loads at 40 % and 10 % of $F_{t,90,u}$, respectively, and ε_{40} and ε_{10} are the measured strains at 40 % and 10 % of $F_{t,90,u}$, respectively.

10.5 Compression properties perpendicular-to-fibre

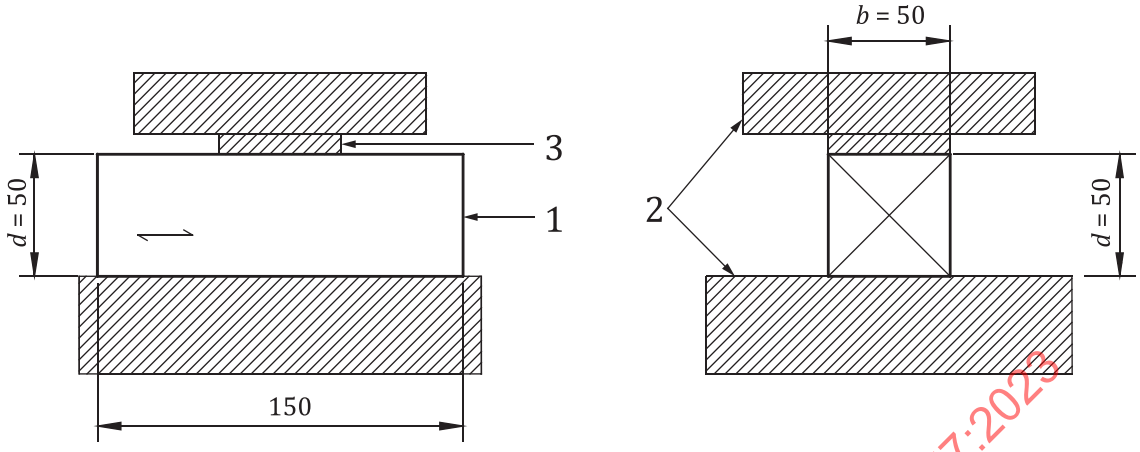
10.5.1 Preparation of test specimens

The dimensions of the test sample shall be made on 50 mm × 50 mm × 150 mm. The specimen shall be prepared in such a way that the primary fibre direction (axis 1) is perpendicular to the loading force. The loaded surfaces shall be accurately prepared to ensure that they are plane and parallel to each other and perpendicular to the test piece axis. The load shall be applied through a 50 mm wide steel bearing plate placed across the upper surface of the specimen, centered on the specimen length, as shown in Figure 8.

NOTE This method cannot be used for engineered bamboo products having either cross section dimension less than 50 mm.

Compression perpendicular to fibre tests shall be conducted such that compression is applied in both 1-2 and 1-3 plane orientations.

Dimensions in millimetres



Key

1 specimen
2 fixtures
3 steel-bearing plate

NOTE ⟿ indicates parallel to fibre orientation

Figure 8 — Perpendicular-to-fibre compressive test specimen schematic

10.5.2 Test procedure

Place the specimen on the test platen as shown in Figure 8. Load shall be applied at a constant rate and the test should be completed within approximately 300 s but not less than 180 s.

10.5.3 Expression of results

The compressive strength $f_{c,90}$ shall be calculated from Formula (10)

$$f_{c,90} = \frac{F_{c,90,u}}{bt} \tag{10}$$

where, $F_{c,90,u}$ is the maximum value of the applied load and b and d are the width and length of the area of bamboo engaged by the steel bearing plate.

11 Test report

The test report shall include the following information:

a) a reference to this document, i.e. ISO 5257:2023;

b) name of laboratory, authority, or organization which performed the tests;

c) date of test report;

d) description of test specimens: species, reference population including population boundary dimensions of test specimens, density, moisture content, fibre orientation;

e) description of the testing method: rate of loading;

f) conditioning of test specimens before and after preparation;

g) number of test specimens;

h) variations from the reference test conditions specified in Clause 8;

i) failure mode of each specimen;

j) calculated values for derived properties;

k) summary statistics of the derived properties for the sample.

The report may include any additional information deemed to be important.