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Bamboo structures — Determination of physical and mechanical properties of bamboo culms — Test methods

Structures en bambou — Détermination des propriétés physiques et mécaniques des tiges de bambou — Méthodes d'essais

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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 of 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 www.iso.org/iso/foreword.html.

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.

This first edition cancels and replaces ISO 22157-1:2004.

Bamboo structures — Determination of physical and mechanical properties of bamboo culms — Test methods

1 Scope

This document specifies test procedures for specimens obtained from round bamboo culms. The data obtained from the test methods can be used to establish characteristic physical or mechanical properties to be used in structural engineering design or for other scientific purposes. This document provides methods for evaluating the following physical and strength properties: moisture content, density, mass per unit length; strength properties parallel to the fibre direction, compression, tension and bending, and strength properties perpendicular to the fibre direction, tension and bending. It also provides methods to estimate moduli of elasticity in bending, compression and tension parallel to fibres, and bending perpendicular to fibres.

The test methods reported in this document are intended for commercial testing applications. The test methods reported in this document are intended for commercial testing applications and can also be adopted as benchmark methods for scientific research.

This document is organized to provide requirements for standard tests to be carried out to determine the material properties of full-culm bamboo as a structural material.

2 Normative references

There are no normative references in this document.

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
bamboo culm
single shoot of bamboo comprised of the entire unaltered bamboo cross-section, which is usually a hollow cylinder except at *nodes* (3.11)

3.2
bamboo clump
clump
cluster of bamboo shoots emanating from two or more rhizomes at the same location

3.3
cross-sectional area
A
area of the net section perpendicular to the direction of the longitudinal axis of the culm

3.4
equilibrium moisture content
moisture content (3.10) at which bamboo is neither gaining moisture from, nor losing moisture to, the environment

3.5
fibre
set of cellulosic fibres in bundles aligned parallel primarily in the longitudinal direction of the culm in the internodes

Note 1 to entry: At nodes, the fibres radiate into the node plate, where they become entangled and their orientation varies greatly.

3.6
fibre saturation point
FSP
moisture level in the bamboo solid material whereby no free liquid water remains in the cell cavities but the cell wall structure is fully saturated by chemically bound water molecules

Note 1 to entry: The maximum content of bound water in bamboo tissue is approximately 30 % by weight of the fully dried tissue.

3.7
green
condition of recently harvested bamboo that has not been dried and has a *moisture content* (3.10) greater than the *fibre saturation point* (3.6)

3.8
internode
hollow region of bamboo culm between two *nodes* (3.11)

3.9
outer diameter
D
diameter of the cross-section of a piece of bamboo taken as the average of two perpendicular measurements made across opposite points on the outer surface

Note 1 to entry: Measurement is usually made at the centre of an internode region.

3.10
moisture content
w
portion of culm weight consisting of water expressed as percentage of oven-dry weight

3.11
node
intermittent transverse diaphragm region located along length of culm separating adjacent *internodes* (3.8), which, when alive, is a location of leaf growth

3.12
traveller specimen
specimen identical to, and stored and conditioned identically to specimens to be tested used to obtain properties whose testing method affects the specimen

Note 1 to entry: Traveller specimens are usually used for determination of moisture content and density.

3.13
wall thickness
δ
thickness of wall of bamboo culm taken as the average of four measurements taken around the circumference of the culm at angular spacings of 90°

Note 1 to entry: Measurement is usually made at the centre of an internode region.

4 Symbols

Symbol	Description	Unit
A	cross-sectional area of the culm defined in 3.3 calculated as: $(\pi / 4) \times [D^2 - (D - 2\delta)^2]$ where D is the outer diameter; δ is the wall thickness	mm^2
A_g	mean cross-sectional area of the gauge portion of the tension test parallel to the fibres specimen described in Clause 11	mm^2
a	shear span (distance from support to nearest application of load) in a four-point bending test described in Clause 12	mm
b	width of tension test specimen gauge region described in Clause 11	mm
D	outer diameter of the bamboo culm defined in 3.9	mm
d	diameter of transverse hole in the tension perpendicular to the fibres specimen described in Clause 14	mm
$E_{c,0}$	compressive modulus of elasticity parallel to direction of fibres	N/mm^2
$E_{t,0}$	tensile modulus of elasticity parallel to direction of fibres	N/mm^2
$E_{m,0}$	apparent flexural modulus of elasticity parallel to direction of fibres	N/mm^2
$E_{m,90}$	circumferential modulus of elasticity	N/mm^2
F	load applied in test	N
F_{ult}	maximum (ultimate) load applied in test	N
$f_{c,0}$	compressive strength parallel to direction of fibres	N/mm^2
$f_{m,0}$	flexural strength parallel to direction of fibres	N/mm^2
$f_{m,90}$	flexural strength perpendicular to direction of fibres	N/mm^2
$f_{t,0}$	tension strength parallel to direction of fibres	N/mm^2
$f_{t,90}$	tension strength perpendicular to direction of fibres	N/mm^2
f_v	shear strength	N/mm^2
h	estimate of neutral axis location for a curved rectangular beam	mm
I_B	second moment of area, or moment of inertia, of the culm section calculated as: $(\pi / 64) \times [D^4 - (D\ 2\delta)^4]$ where D is the outer diameter; δ is the wall thickness	mm^4
L	length of test piece or clear span in bending between centres of supports (Clause 12)	mm
M_{ult}	maximum moment	N·mm
m_e	mass of test specimen	g
m_i	initial mass of test specimen	G
m_0	oven-dry mass of test specimen	g
q	mass per unit length	g/mm kg/m
q_{12}	mass per unit length normalized for 12 % moisture content	g/mm kg/m
R	characteristic radius of the centreline of the culm wall, calculated as $0{,}5(D - \delta)$	mm

V	volume of test piece	mm^3
V_0	volume of green test piece	mm^3
w	ratio of mass of embodied water to mass of oven-dry specimen, equivalent to moisture content defined in 3.10.	—
Δ	deflection	mm
δ	culm wall thickness, defined in 3.13	mm
ε	strain	mm/mm
ρ	density, when converted as indicated in 8.4	g/mm^3 kg/m^3
ρ_{12}	density normalized for 12 % moisture content, when converted as indicated in 8.4	g/mm^3 kg/m^3
ρ_{test}	density under conditions of test, when converted as indicated in 8.4	g/mm^3 kg/m^3

5 General requirements

5.1 Temperature and humidity

Unless required by specific conditioning protocols, test specimens shall be stored, conditioned and tested in an environment having a temperature range of (23 ± 3) °C, and relative humidity range of (65 ± 5) %.

However, 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, alongside the moisture content determined for individual specimens.

5.2 Rate of load application

The rate of load application of the testing machine shall be selected such that failure is reached within (300 ± 120) s. Tests that fail in less than 30 s shall be removed from analysis. The load shall be applied continuously without interruption at the required rate throughout the test. For tests run in displacement control, the rate of traverse of the movable head of the testing machine shall be the free running or no-load speed of the head for mechanical drive type machines, and the loaded head speed for hydraulic or servo-hydraulic driven testing machines. The time to failure for each individual specimen shall be recorded in the test report.

5.3 Calibration

All apparatus and testing equipment used in obtaining data shall be calibrated at sufficiently frequent intervals to ensure accuracy. A record of errors observed before calibration, the date and time of calibration and observations following calibration shall be maintained.

5.4 Test report

The test report shall include the following information:

a) a reference to this document, i.e. ISO 22157;

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

c) the details of the test specimens, as noted in 6.3;

d) a description of the sampling including:

   1) the method of grading and grade, if applicable;

   2) the size of the sample; and

   3) the moisture content at the time of sampling.

e) variations from the reference test conditions specified in Clause 5;

f) the equipment used, and any other information which may influence the use of the test results;

g) raw test data, including:

   1) the dimensions of the specimen including measured values of at least D, δ and L;

   2) the location of specimen along culm (B, M or T);

   3) the measured values of moisture content from specimen or companion traveller specimens obtained at the time of testing;

   4) the measured values of density and density adjusted to 12 % moisture content from specimen or traveller specimens obtained at the time of testing;

   5) the load-displacement diagram up to failure for each specimen;

   6) the observed location and mode of failure for each specimen;

   7) the calculated moduli and/or strength values;

   8) the range of data used to calculate the modulus of elasticity;

   9) the time to failure for each specimen;

   10) any other information which may influence the use of the test results;

h) the mean and coefficients of variation (and/or standard deviation) of the obtained test data; and

i) any additional information deemed to be important to interpretation of test data.

6 Sampling and storage of specimens

6.1 Sampling

Sampling should be representative of the population which test results are intended to represent and be appropriate for the objective of the testing program. Sampling methodology shall be included in the test report.

Bamboo material for any particular species shall be taken:

— in the case of tests on properties for commercial purposes: from a number of different localities, representative of different growth conditions throughout the geographical range of the species;

— in the case of quality control as required in a strength grading protocol or standard: from a randomly selected sample from a batch as required by the protocol or standard.

From each locality, the selection, marking, etc., of the different consignments, as well as all the details of the various clumps and culms, shall be reported.

Culms are to be cut to length taking care to record the provenance of a specimen along the culm in accordance to 6.3. For specimens that are to be used to determine bending strength, refer to Clause 12 for minimum lengths.