INTERNATIONAL STANDARD

ISO 11093-8

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Paper and board — Testing of cores —

Part 8:
Determination of natural frequency and flexural modulus by experimental modal analysis

Papier et carton — Essais des mandrins —
Partie 8: Détermination de la fréquence propre et du module de flexion par analyse modale expérimentale

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 11093-8 was prepared by Technical Committee ISO/TC 6, *Paper, board and pulps*, Subcommittee SC 3, *Dimensions and grammages of paper, board and pulp products*.

ISO 11093 consists of the following parts, under the general title *Paper and board — Testing of cores*:

— *Part 1: Sampling*

— *Part 2: Conditioning of test samples*

— *Part 3: Determination of moisture content using the oven drying method*

— *Part 4: Measurement of dimensions*

— *Part 5: Determination of characteristics of concentric rotation*

— *Part 6: Determination of bending strength by the three-point method*

— *Part 7: Determination of flexural modulus by the three-point method*

— *Part 8: Determination of natural frequency and flexural modulus by experimental modal analysis*

— *Part 9: Determination of flat crush resistance*

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Paper and board — Testing of cores —

Part 8:
Determination of natural frequency and flexural modulus by experimental modal analysis

1 Scope

This part of ISO 11093 specifies a method for the determination of the flexural modulus by using experimentally measured natural frequencies in the free-free mode of transverse vibration of cylindrical paper and board cores, which meet the following criteria:

— internal diameter: 50 mm to 350 mm;

— minimum wall thickness: 0,02 × internal diameter or not less than 2,0 mm;

— minimum length of core: 8 × internal diameter.

NOTE — For the determination of the flexural modulus by the three-point method, see ISO 11093-7.

2 Normative references

The following standards contains provisions which, through reference in this text, constitute provisions of this part of ISO 11093. 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 11093 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 11093-1:1994, *Paper and board — Testing of cores — Part 1: Sampling.*

ISO 11093-2:1994, *Paper and board — Testing of cores — Part 2: Conditioning of test samples.*

ISO 11093-3:1994, *Paper and board — Testing of cores — Part 3: Determination of moisture content using the oven drying method.*

ISO 11093-7:1997, *Paper and board — Testing of cores — Part 7: Determination of flexural modulus by the three-point method.*

3 Definitions

For the purposes of this part of ISO 11093, the following definitions apply.

3.1 natural frequency, f: First frequency a structure vibrates in, depending on its material, shape and supporting system, when an impulse is applied to it.

3.2 flexural modulus, E: Material property which, together with core dimensions, describes the resistance of the core to bending deflection.

4 Principle

In the experimental modal analysis, the test piece is considered a “beam” and Timoshenko's beam theory for isotropic materials is applied in evaluating transverse vibrations. In this theory, the influence of rotary inertia and shear deformations on transverse vibrations is included. During the test, the test piece is supported so that it is free to vibrate in the transverse direction. The flexural modulus is calculated as described in clause 8.

5 Apparatus

5.1 Test-piece support

The basic idea is to measure the first natural frequency in the free-free mode of transverse vibration. To ensure free-free boundary conditions in the lateral direction, the test piece is supported by a wire and hanging with its axis in the vertical direction (see figure 1). The minimum length of the support wire (1) is about 300 mm. The supporting system consists of two clamps and the wire. An example of attaching the clamps is shown in figure 2. The mass of the clamps should be less than 0,01 × mass of the test piece. The angle α (see figure 2) should be more than 45°. The distance of the fixing screw from the edge of the core should be 5 mm to 10 mm.

5.2 The experimental modal analysis system

The first natural frequency is measured with a signal analyser. The test piece is impacted by a hammer in the direction (Z-direction) perpendicular to the plane of the support wires (XY-plane) (see figure 1). The impulse response is measured by a piezoelectric accelerometer at one end of the test piece mounted with its axis in the Z-direction (see figure 1). The sensitivity of the accelerometer shall be 8 mV/g to 100 mV/g, the frequency range limit of the accelerometer shall be 0,1 Hz to 10 000 Hz and the maximum mass of the accelerometer shall be 0,01 × mass of the test piece. The measured signal is analysed using a signal analyser and the frequency of the lowest mode of bending vibrations is determined from the frequency response function.

6 Test piece

6.1 Sampling

Samples shall be taken in accordance with ISO 11093-1.

6.2 Test-piece size

The minimum length of the test piece shall be 8 times the internal diameter of the core.

NOTES

1 If the test piece is too short, it is not possible to read the response of the frequency analysis.

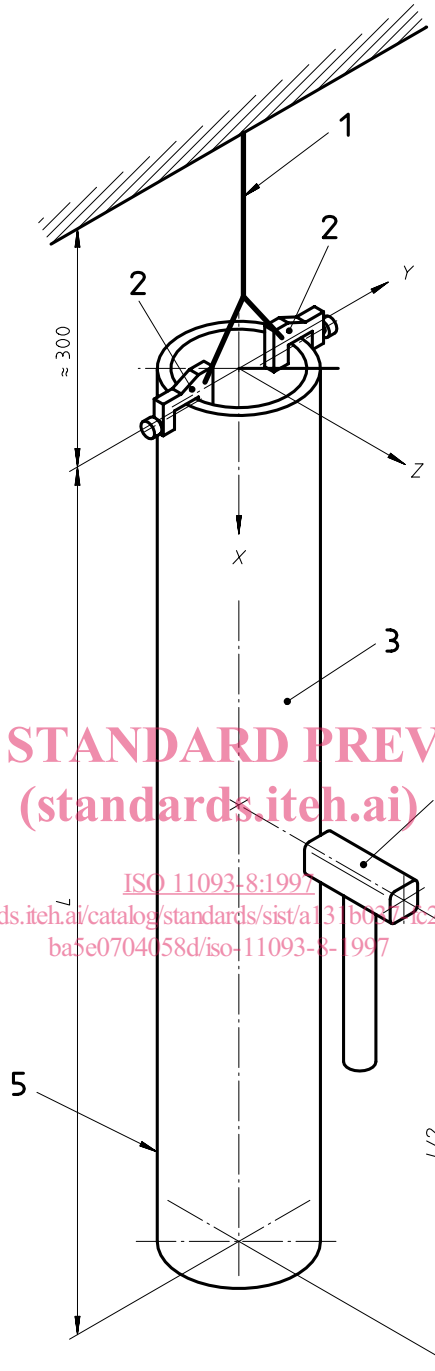
2 The calculated flexural modulus E is more accurate for long test pieces.

6.3 Conditioning

The test piece shall be conditioned in accordance with ISO 11093-2. Measure the moisture content of the test piece in accordance with ISO 11093-3.

In practice, the test piece shall be conditioned and dried so that the moisture content shall be equal to that specified for the lot.

Dimensions in millimetres



Key

1 Support wire
2 Clamps
3 Test piece
4 Hammer
5 Accelerometer

Figure 1 — Schematic drawing of the test

Dimensions in millimetres

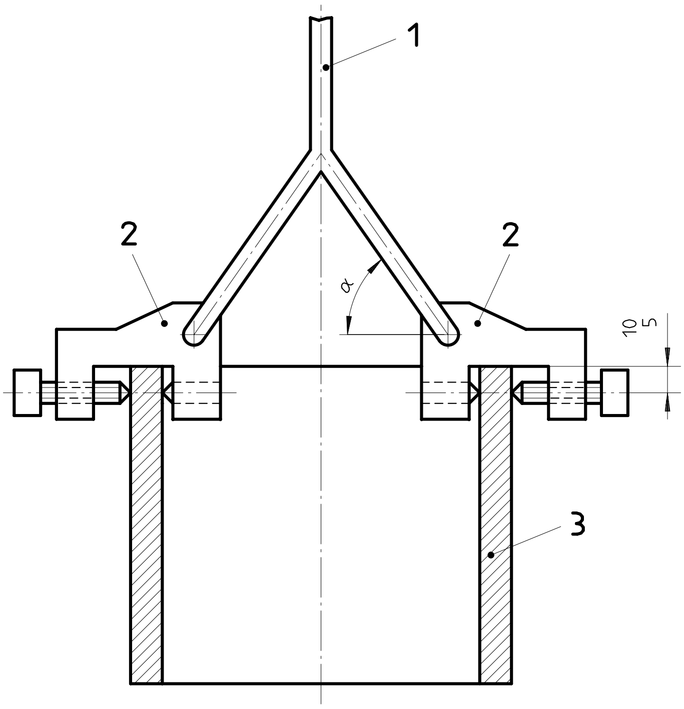


Figure 2 — Schematic drawing of the test-piece support

7 Procedure

Carry out the test under the same atmospheric conditions as those used to condition the test piece.

Impact the test piece in the Z-direction in the middle of the length of the test piece by means of a hammer as shown in figure 1. After the impact, the first natural frequency in bending shall be read from the frequency response of the analysis. The obtained value f is used in formula (1) to calculate the flexural modulus of each tested test piece.

NOTE — 1, 2 and 3: see figure 1.

The flexural modulus E, or Young's modulus in bending, is calculated, in newtons per square millimetre, using the formula

$$E = 7{,}88 \times 10^{-8} \times \frac{f^2 \cdot m \cdot L^4 \cdot Q}{I} \qquad \ldots (1)$$

where

f is the measured first natural frequency, in hertz;

m is the mass per unit length of the test piece, in kilograms per metre;

L is the length of the test piece, in millimetres;

Q is a dimensionless coefficient, which is calculated using formula (3);

l is the second moment of area of the core cross-section, which is calculated using formula (2), in millimetres to the power four.

I is calculated according to the formula

$$I = \frac{\pi}{64}\left(D^4 - d^4\right) \quad \ldots(2)$$

where

D is the outer diameter of the core, in millimetres;

d is the internal diameter of the core, in millimetres.

The coefficient Q is calculated using the formula

$$Q = \frac{82{,}66I}{AL^2} + 1 \quad \ldots (3)$$

where A, the area of the core cross-section, in square millimetres, is calculated using the formula

$$A = \frac{\pi}{4}\left(D^2 - d^2\right) \quad \ldots (4)$$

9 Test report

The test report shall include the following particulars:

a) reference to this part of ISO 11093;

b) type and designation of the cores tested;

c) place and date of sampling;

d) place and date of testing;

e) number of test pieces tested;

f) core dimensions;

g) measured moisture content;

h) L and f;

i) individual and mean values for E;

j) deviations, if any, from this part of ISO 11093;

k) date and signature.

ICS 85.080

Descriptors: paper, paperboards, cores, spool cores, tests, mechanical tests, determination, flexural strength.

Price based on 5 pages