
Paper and board — Testing of cores —

Part 7:

Determination of flexural modulus by the
three-point method

Papier et carton — Essais des mandrins —

Partie 7: Détermination du module de flexion par la méthode à trois points





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Paper and board — Testing of cores —

Part 7:

Determination of flexural modulus by the three-point method

1 Scope

This part of ISO 11093 specifies a method for the determination, by the three-point method, of the flexural modulus of cylindrical paper and board cores which meet the following criteria:

- internal diameter: 50 mm to 350 mm;
- minimum wall thickness: $0,05 \times$ internal diameter, but not less than 10,0 mm;
- minimum length of core: $10 \times$ internal diameter, but not less than 1 000 mm.

If the flexural modulus has to be used for the calculation of a paper core's natural frequency, ISO 11093-8[2] applies instead of this International Standard.

2 Normative references

The following referenced documents are indispensable for the application 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 11093-1, Paper and board — Testing of cores — Part 1: Sampling

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

3 Terms and definitions

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

3.1

flexural modulus

E

material property which, together with core dimensions, describes the resistance of the core to traction or bending deflection

4 Principle

In order to determine the flexural modulus, a static bending test is conducted on the test piece. The test piece is considered as a “beam” and the classic beam theory for the deflection of “slender beams” is applied. During the test, the test piece is supported at its ends and loaded transversally by a load applied by a hanging weight. Special measures are undertaken to avoid permanent deformation of the test piece and to ensure the validity of the equation, used for calculation.

The flexural modulus is calculated as described in Clause 8.

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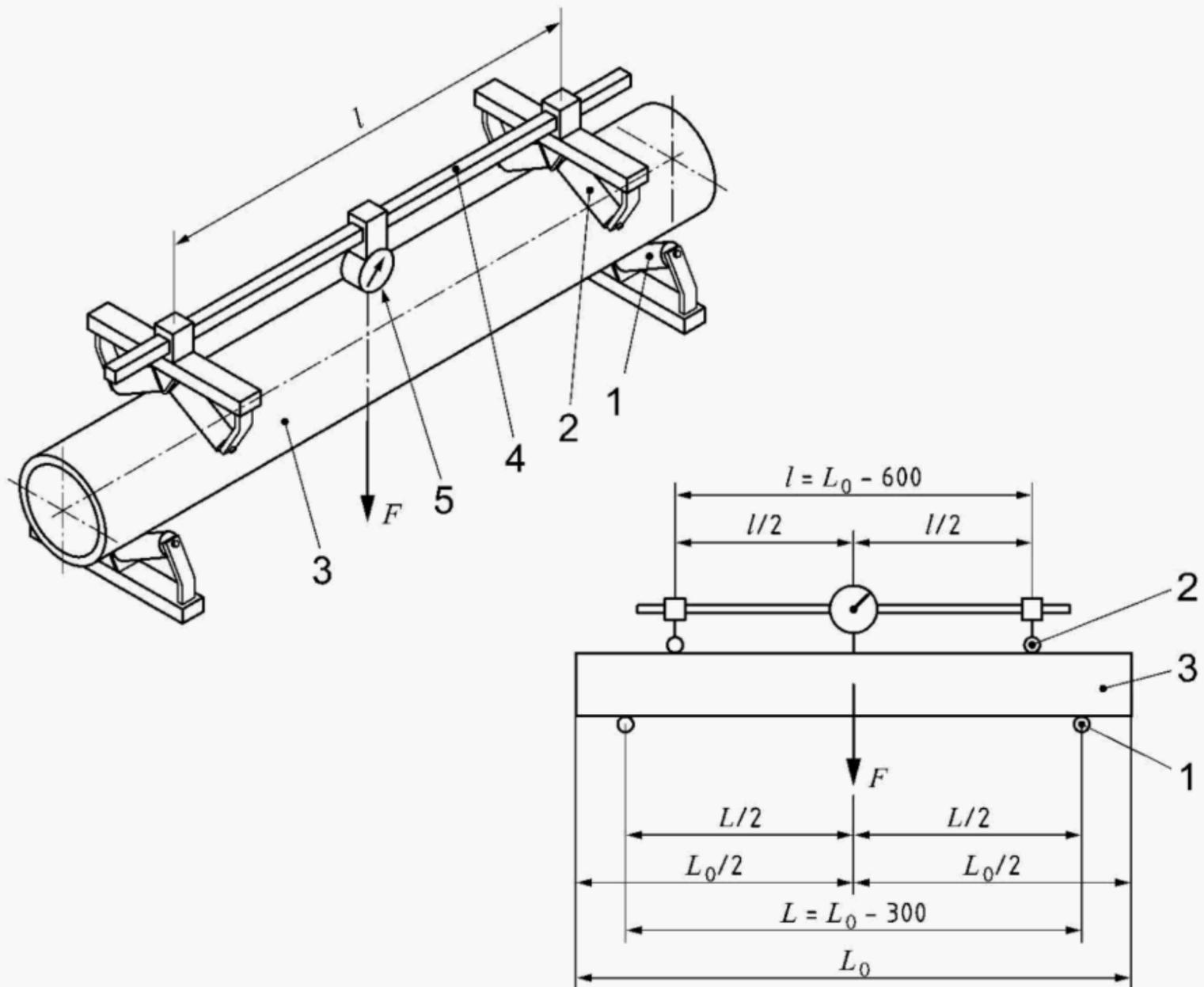
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Dimensions in millimetres



Key

- 1 lower bearing
- 2 upper bearing
- 3 test piece
- 4 support bar
- 5 dial gauge
- F load (force)
- L_0 length of test piece, length of paper core
- L centre-to-centre distance of the lower bearings
- l centre-to-centre distance of the upper bearings

Figure 2 — Schematic drawing of the measuring set-up

5.3 Load

The magnitude of the load to be used in the test can be estimated using Equation (2). The load F is applied to the test piece by a belt loaded with hanging weights. The width of the belt shall be approximately 50 mm (see Figure 3). The belt shall have an opening to allow the shaft of the displacement gauge to rest on the test piece.

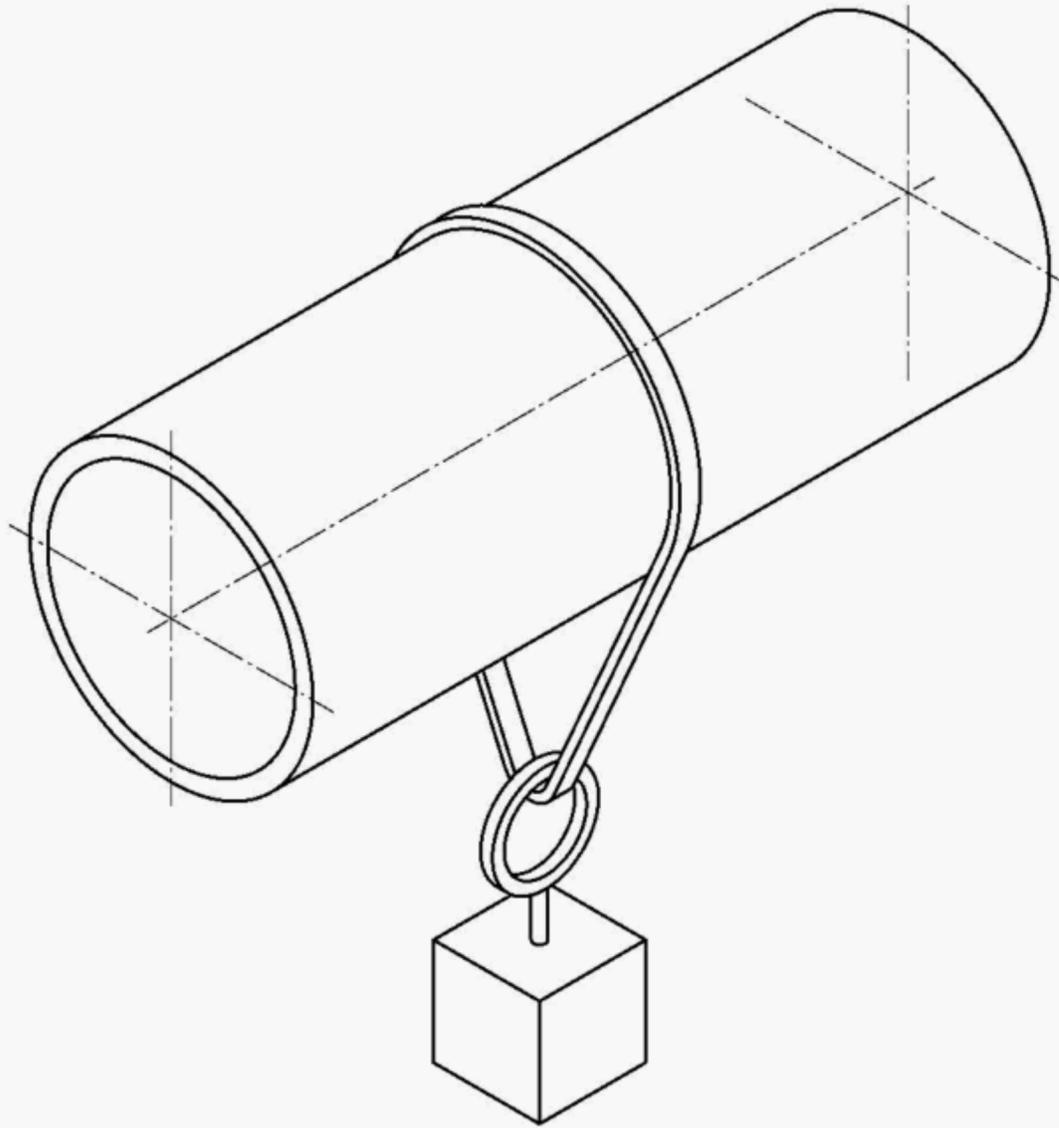


Figure 3 — Schematic drawing of the loading system

Alternatively, the load can be applied by a testing machine capable of applying the load using a displacement rate of $(10 \pm 0,1)$ mm/min and measuring the load to an accuracy of $\pm 0,1$ N.

6 Test piece

6.1 Sampling

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

6.2 Test-piece size

Prepare at least five test pieces such that their lengths L_0 are 10 times the internal diameter of the paper or board core. If the calculated length is less than 1 000 mm, the test piece length shall be $(1\ 000 \pm 2)$ mm.

6.3 Conditioning

In practice, the test piece shall be dried such that the moisture content measured in accordance with ISO 11093-3 shall be equal to that specified for the lot.

7 Procedure

7.1 General

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

The core's outer and inner diameter, D and d respectively, shall be determined with an accuracy of $\pm 0,1$ mm.

7.2 Positioning of bearings and measuring device

The length of the test piece L_0 shall be determined with an accuracy of ± 1 mm. The test piece shall be centred on the lower bearings with a tolerance of ± 2 mm.

Position the lower bearings such that their centre-to-centre distance L is 300 mm less than the length of the test piece L_0 and the upper bearings such that their centre-to-centre distance l is 600 mm less than the length of the test piece, each with an accuracy of ± 2 mm.

The centres of the lower and upper bearings, and the positions of the displacement gauge and the application of force in the direction of the test piece's axis shall be centred with respect to the centre of the test piece to an accuracy of ± 2 mm.

The displacement gauge is positioned centrally on the test piece. The displacement gauge is vertically attached on a support bar. The deflection is measured on the upper side of the test piece.

7.3 Application of loading

Apply the load F by hanging an appropriate weight on the belt which is placed at the midpoint of the measuring length L of the test piece (see Figure 3). The hanging weight shall be applied slowly.

Alternatively, the loading can be applied in a material-testing machine. The loading rate (rate of advance) shall be 10 mm/min.

The load shall be such that the deflection f is between 0,20 mm and 0,70 mm (see Clause 9).

7.4 Determination

If the load is applied by a hanging weight, within 2 s after application of the loading, the deflection recorded by the displacement gauge shall be read. If the load is applied by a material-testing machine, determine the load required to produce a deflection f between 0,20 mm and 0,70 mm. By applying the values F , L , l and f to be used in Equation (1), the flexural modulus for each test piece shall be calculated.

Repeat 7.2 to 7.4 for additional test pieces.

8 Calculation of the flexural modulus

The flexural modulus E , or Young's modulus, is calculated according to Equation (1), which is developed from the bending theory for slender beams.

$$E = \frac{2Fl(3L-l)}{2 \cdot 3\pi \left(\frac{D^4}{f} - \frac{d^4}{f} \right)} \quad (1)$$

where

- F is the applied transversal load on the test piece, expressed in newtons; the load shall be positioned in such a way that the deflection f lies between 0,20 mm and 0,70 mm;
- L is the centre-to-centre distance of the lower bearings, expressed in millimetres;
- l is the centre-to-centre distance of the upper bearings, expressed in millimetres;
- f is the difference, expressed in millimetres, between the loaded and unloaded deflection measured in the direction of the applied load;
- D is the external diameter of the core, expressed in millimetres;
- d is the internal diameter of the core, expressed in millimetres.

The flexural modulus shall be specified in newtons per square millimetre, to the nearest integer.

EXAMPLE $F = 200 \text{ N}$, $L = 1\,700 \text{ mm}$, $l = 1\,400 \text{ mm}$, $f = 0,54 \text{ mm}$, $D = 106 \text{ mm}$, $d = 76 \text{ mm}$.

The calculation using Equation (1) gives: $E = 6\,136 \text{ N/mm}^2$.

9 Estimation of required force

On the assumption of a deflection of about 0,5 mm and an assumed flexural modulus E_{ass} , the required load F , in newtons, can be approximately calculated using Equation (2):

$$F \approx \frac{3 \times \pi \times 0,5^2 \times E_{\text{ass}}}{2 \times I \times (3L - l)} \times \frac{D^4 - d^4}{4} \quad (2)$$

where

E_{ass} is the assumed value for the flexural modulus, expressed in newtons per square millimetre;

D , d , L and l are defined after Equation (1).

EXAMPLE $E_{\text{ass}} = 6\,000 \text{ N/mm}^2$, $L = 1\,700 \text{ mm}$, $l = 1\,400 \text{ mm}$, $D = 106 \text{ mm}$, $d = 76 \text{ mm}$.

The calculation using Equation (2) gives: $F \approx 181 \text{ N}$.

10 Test report

The test report shall include the following information:

- a) 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) measured moisture content;
- g) core dimensions L_0 , D and d ;
- h) L , l (actual sizes), F and f ;
- i) individual and mean values for E ;
- j) whether the load was applied with a hanging weight or a material-testing machine;
- k) any deviation from this part of ISO 11093 that may have affected the results.

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