
**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



Reference number
ISO 11093-7:2011(E)

© ISO 2011



COPYRIGHT PROTECTED DOCUMENT

© ISO 2011

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

Contents

Page

Foreword	iv
1 Scope	1
2 Normative references	1
3 Terms and definitions	1
4 Principle	1
5 Apparatus	2
5.1 Test-piece support	2
5.2 Measuring device	2
5.3 Load	3
6 Test piece	4
6.1 Sampling	4
6.2 Test-piece size	4
6.3 Conditioning	4
7 Procedure	4
7.1 General	4
7.2 Positioning of bearings and measuring device	5
7.3 Application of loading	5
7.4 Determination	5
8 Calculation of the flexural modulus	5
9 Estimation of required force	6
10 Test report	6
Bibliography	7

www.iso.org

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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. 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.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 11093-7 was prepared by Technical Committee ISO/TC 6, *Paper, board and pulps*.

This second edition cancels and replaces the first edition (ISO 11093-7:1997), which has been technically revised. The following amendments have been made compared with ISO 11093-7:1997:

- a) adaptation to editorial rules for International Standards;
- b) as the effect of transverse frame on deflection is so low with usual reel core measurements that it can be neglected given the usual variation in materials, the Timoshenko factor has been deleted along with the corresponding equation.

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*

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.

5 Apparatus

5.1 Test-piece support

The test piece is supported at each end by two rolls arranged like a vee, referred to as the *lower bearings* (see Figure 1). The angle between the two rolls shall be $120^\circ \pm 2^\circ$. The diameter a of the rolls shall be (30 ± 1) mm. The width b shall be large enough to allow the test piece to rest on the lateral surface area of the rolls. At an angle of 120° , the theoretical minimum value of b is half the outer diameter D of the core.

Dimensions in millimetres

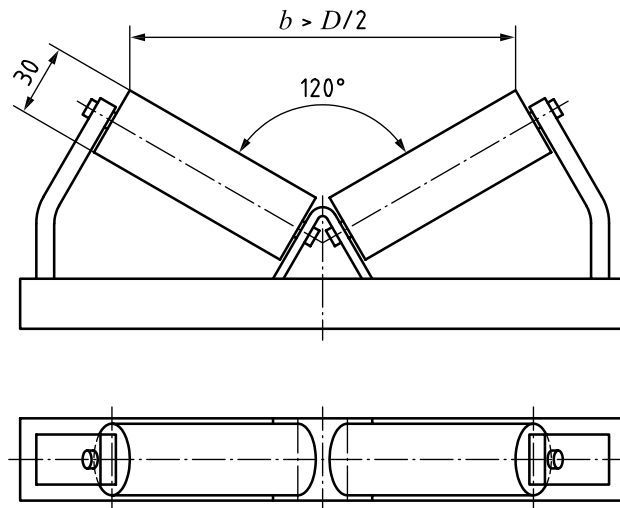


Figure 1 — Schematic drawing of the bearings

5.2 Measuring device

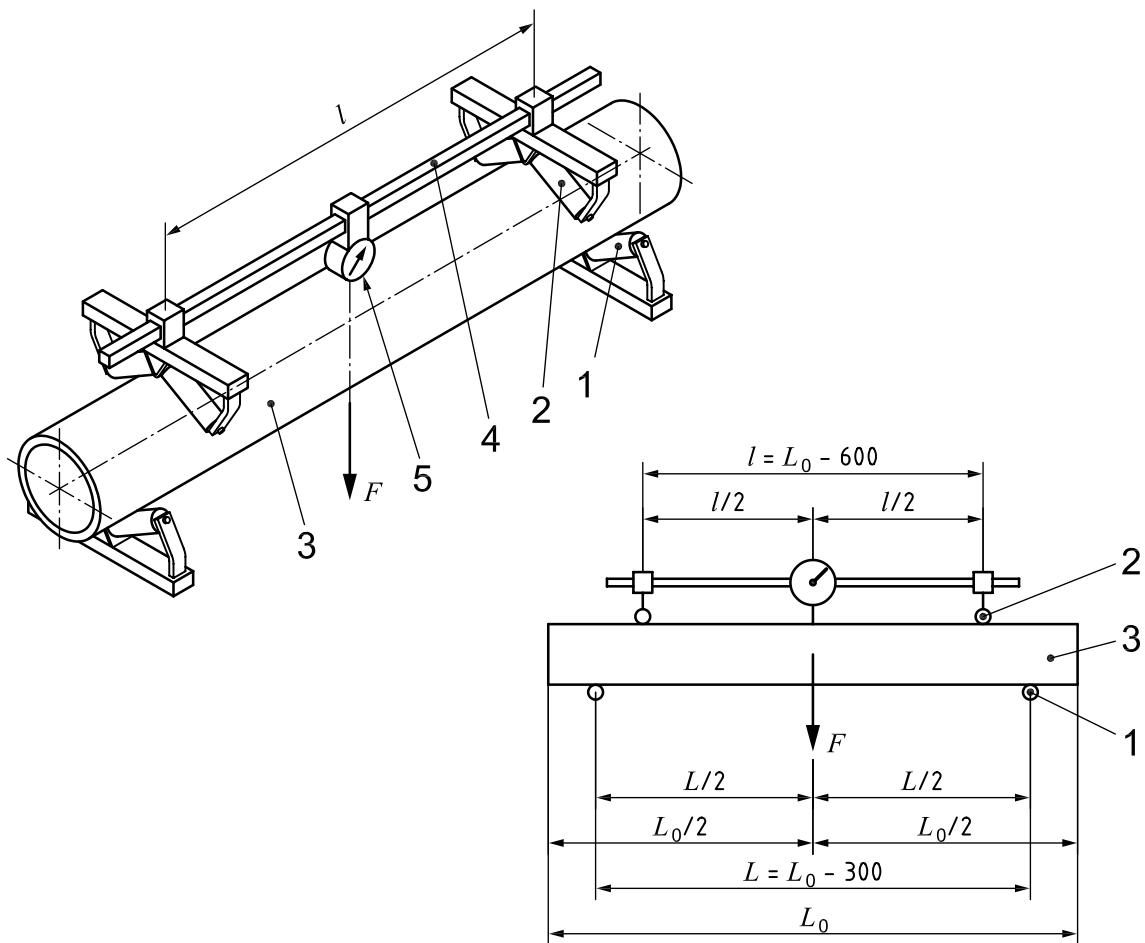
The measuring device consists of two rolls arranged like a vee, referred to as the *upper bearings*, a support bar on which the upper bearings are mounted, and a displacement gauge. The lower and upper bearings are arranged with mirror-image symmetry. The measuring device is placed on the test piece.

The change in deflection f of the test piece is measured in the direction of the applied force using a displacement gauge (see Figure 2).

If a material-testing machine is used to apply the load (see 5.3), it may also be used to measure the deflection of the test piece. It shall be accurate to $\pm 0,01$ mm.

The tolerances of the distances and the force F are defined in Clause 7.

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.

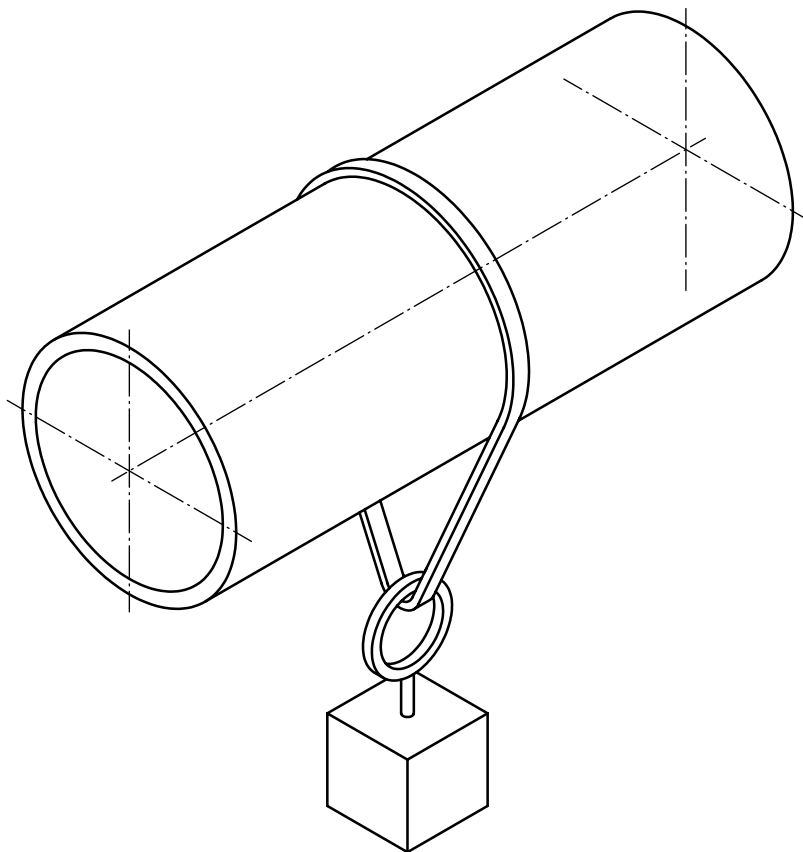


Figure 3 — Schematic drawing of the loading system

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.

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

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.

ISO 11093-7:2011(E)

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):

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

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.

Bibliography

- [1] ISO 11093-2, *Paper and board — Testing of cores — Part 2: Conditioning of test samples*
- [2] ISO 11093-8, *Paper and board — Testing of cores — Part 8: Determination of natural frequency and flexural modulus by experimental modal analysis*

© ISO 2011. All rights reserved.

ICS 85.060

Price based on 7 pages