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Paper and board — Determination of bending stiffness — General principles for two-point, three-point and four-point methods

Papier et carton — Détermination de la rigidité à la flexion — Principes généraux pour les méthodes à deux points, à trois points et à quatre points

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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

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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 5628 was prepared by Technical Committee ISO/TC 6, *Paper, board and pulps*, Subcommittee SC 2, *Test methods and quality specifications for paper and board*.

This second edition cancels and replaces the first edition (ISO 5628:1990), which has been technically revised.

The main differences between this edition and the previous edition are the following:

— the equations for bending stiffness for two-point and three-point bending have been harmonized;

— geometrical conditions for test pieces have been added;

— some additional aspects of corrugated board have been added for four-point bending.

Introduction

Bending stiffness is regarded as an important property of paper and board, and a large number of test methods have been used for its determination. This is a result, in part at least, of the wide range in the bending stiffness of paper and board. For paper and board in the grammage range 50 g/m^2 to 500 g/m^2, bending stiffness might vary by a factor of over 1 000. This wide variation is reflected in the design of instruments intended for the measurement of this property.

A second factor to be taken into account is that, in general terms, bending stiffness (as defined here) can only be determined with accuracy within certain limits with regard to the degree of deformation imposed upon the test piece. These limits depend on the dimensions of the test piece and on the test method used.

This International Standard is intended to enable the bending stiffness (as defined here) to be measured and described in a consistent way, despite the variations in material type and instrument design. It will be found that many commercially available instruments can be regarded as giving results in accordance with this International Standard for only part of the range of bending stiffness, or for only some of the materials for which they were originally designed. It is intended, therefore, that this International Standard will be used as the basis for preparing detailed methods for determining bending stiffness, using particular instruments.

Paper and board — Determination of bending stiffness — General principles for two-point, three-point and four-point methods

1 Scope

This International Standard specifies three test methods for determining the bending stiffness of paper and paperboard. The test methods differ in the type of loading mode, thus giving rise to the two-point, three-point and four-point bending test methods.

For paper and paperboard in a low thickness range, the two-point bending method and the three-point bending method are suitable.

For corrugated fibreboard and board with a higher thickness, the four-point bending method is recommended.

The measurement conditions are defined in such a way that the test piece is not subjected to any significant permanent deformation during the test, nor is the range of validity of the equations for calculating the bending stiffness exceeded.

In these bending tests, the test pieces of paper and board are regarded as “beams” as defined by the science of the strength of materials, see Reference [1].

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 186, *Paper and board — Sampling to determine average quality*

ISO 187, *Paper, board and pulps — Standard atmosphere for conditioning and testing and procedure for monitoring the atmosphere and conditioning of samples*

ISO 534, *Paper and board — Determination of thickness, density and specific volume*

ISO 3034, *Corrugated fibreboard — Determination of single sheet thickness*

3 Terms and definitions

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

3.1
bending stiffness
S_b
resistance that a test piece offers to bending, in the region of elastic deformation

NOTE The theories used for the determination of bending stiffness are derived under the condition that the test piece is perfectly flat at the beginning of the test. In a real situation, the test piece always deviates from flatness. It is, however, not possible to give recommendations on the magnitude of such deviations (such as curl, twist, cockle or other deviations) that can be present and still produce a valid test.

4 Symbols and units

The following symbols are used for the equations in this International Standard.

Table 1 — Symbols and units

Symbol	Unit	Meaning
b	mm	test piece width in the direction of the bending axis
E	MPa (N/mm^2)	modulus of elasticity
f	mm	linear deflection
F	N	force
f_{max}	mm	maximum linear deflection
I	mm^4	second moment of inertia
l	mm	bending length
l_1	mm	distance in the four-point method
l_2	mm	bending length in the four-point method
S_b	N·mm	bending stiffness
t	mm	test piece thickness
α	° (degree)	bending angle
α_{max}	° (degree)	maximum bending angle
ε	% (mm/mm)	strain
ε_{max}	% (mm/mm)	maximum strain

5 Theory

For a beam of a homogeneous material, with equal thickness and a constant modulus of elasticity in the plane of the paper or board, the bending stiffness S_b (per unit width b) may be derived from the product of the modulus of elasticity, E, and the second moment of inertia, I, of the test piece, divided by the width, b, of the test piece as shown in Equation (1):

$$S_b = \frac{E \cdot I}{b} \tag{1}$$

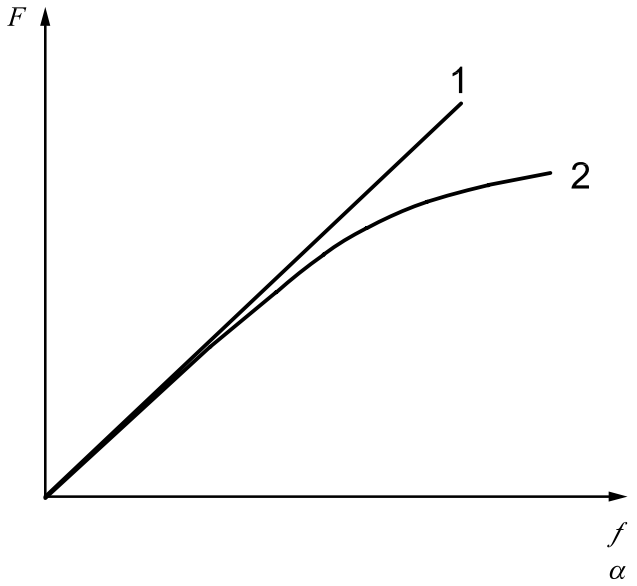
From a testing point of view, the bending stiffness, S_b, may be evaluated in three principally different ways:

a) From the maximum slope of the curve achieved from recording force versus linear deflection (F/f), or force versus angular deflection (F/α), see Figure 1[2]. The rate of testing shall be reported.

b) Applying a linear deflection or angular deflection and recording the force after a specified time[2]. This International Standard gives suggestions for maximum allowable deflections for the various beam-bending methods. The time of application shall be reported.

c) Applying a force and recording the linear deflection or angular deflection after a specified time (References [2], [3], [5]). This International Standard gives suggestions for maximum allowable deflections for the various beam-bending methods. The time of application shall be reported.

NOTE Suggestions for allowable deflections only apply to principles b) and c).



Key

1 maximum slope of curve
2 true curve
F force
f linear deflection
α angular deflection

Figure 1 — Schematic curve of force versus linear deflection or force versus angular deflection of a paper or board

6 Different bending test methods

6.1 Two-point bending method

The two-point method is suitable for paper and low-thickness board. For corrugated board, the two-point method is not recommended.

The bending according to the two-point bending method can be performed in two ways.

In Figure 2, the beam-shaped test piece is clamped at one end and subjected to a force, F, acting perpendicular to the surface of the test piece at the start of the test, at a bending length, l, from the clamp. The linear deflection, f, of the test piece is the shift in the point of application of the force in the direction in which it acts.

In Figure 3, the beam-shaped test piece is clamped at one end in a clamp that rotates and is subjected to a force, F, acting perpendicular to the surface of the test piece at the start of the test, at a bending length, l, from the clamp. The bending angle, α, is the angle through which the clamp is rotated during the test.