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**Paper and board — Determination of  
bending resistance —**

**Part 1:  
Constant rate of deflection**

*Papier et carton — Détermination de la résistance à la flexion —  
Partie 1: Valeur à gradient de déflexion constant*



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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 2493-1 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 first edition, together with ISO 2493-2, cancels and replaces ISO 2493:1992, which has been technically revised. In the revision, ISO 2493:1992 was divided into two parts due to different measuring principles. This part of ISO 2493 describes the constant rate of deflection and ISO 2493-2 describes the Taber-type tester. This part also gives the possibility to use a smaller bending length and a lower bending angle if needed. Optional calculation in index form has been added. A precision statement has been added in informative Annex A.

ISO 2493 consists of the following parts, under the general title *Paper and board — Determination of bending resistance*:

- *Part 1: Constant rate of deflection*
- *Part 2: Taber-type tester*

## Introduction

In ISO 2493:1992, two principles for determining the bending resistance were incorporated in the same standard, although the two principles were very different.

One principle involved the deflection of an equal number of test pieces with opposing surfaces towards the direction of deflection; this principle is described in this part of ISO 2493.

The other principle used a Taber-type tester, where the test piece was inserted and deflected to the top side and then, without changing the test piece, it was deflected in the opposite direction. This principle is described in ISO 2493-2. The method is based on TAPPI Test Method T 489 om-04<sup>[4]</sup>.

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# Paper and board — Determination of bending resistance —

## Part 1: Constant rate of deflection

### 1 Scope

This part of ISO 2493 specifies procedures, based on the two-point loading principle, for determining the bending resistance of paper and board.

NOTE 1 See ISO 5628<sup>[1]</sup> for a detailed description of the two-point loading principle.

This part of ISO 2493 applies to the measurement of the bending resistance within the range 20 mN to 10 000 mN. It is not applicable to corrugated board but can be applicable to the components of such board.

The bending angle is 15° and the bending length is 50 mm.

For samples having a bending resistance that is too low to measure with a bending length of 50 mm, a shorter bending length, i.e. 10 mm, can be used.

**IMPORTANT — The results obtained when using different bending lengths will not be comparable.**

For boards that tend to be permanently deformed if bent through 15°, the half bending angle, i.e. 7,5°, can be used.

NOTE 2 Taber-type testers and testers using the principle of constant rate of deflection do not give comparable results. For this reason, ISO 2493:1992 has been divided into two parts.

### 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 536, *Paper and board — Determination of grammage*

### 3 Terms and definitions

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

**3.1 bending force**  
force required to bend a rectangular test piece clamped at one end, the force being measured under the conditions specified in this part of ISO 2493

**3.2 bending resistance**  
mean of all valid readings of the measured **bending force** (3.1) calculated as specified in this part of ISO 2493

NOTE Bending resistance is expressed in newtons or millinewtons.

**3.3 bending length**  
constant radial distance between the clamp and the position on the test piece at which the force is applied

NOTE See *l* in Figure 1.

**3.4 bending angle**  
angle through which the clamp rotates while moving from its initial position to the position at which the bending resistance is measured

**3.5 free length**  
total length of the test piece that projects from the clamp

NOTE See *L* in Figure 1.

**3.6 bending resistance index**  
bending resistance divided by the grammage to the third power

### 4 Principle

Measurement of the force required to bend a test piece clamped at one end through a specified angle, where the force is applied at a specified bending length (50 mm or 10 mm). The bending resistance is calculated as a mean of the measured forces.

### 5 Apparatus

**5.1 Cutter**, for preparing test pieces of the required accuracy, for example, a die cutter or a double-knife cutter.

**5.2 A bending-resistance tester** (see Figure 1), consisting of the following components.

**5.2.1 Clamp** (5), not less than 38 mm wide and not less than 20 mm long, adjustable in the direction perpendicular to the plane of the test piece, to grip the test piece. In its starting position, the clamp holds the test piece in the vertical plane. The clamp shall be capable of being rotated about the axis formed by the clamping line at a constant speed of  $(5,0 \pm 0,5)^\circ/\text{s}$  through a bending angle of  $(15,0 \pm 0,3)^\circ$ . If necessary, a bending angle of  $(7,5 \pm 0,3)^\circ$  may be used; see Clause 10.

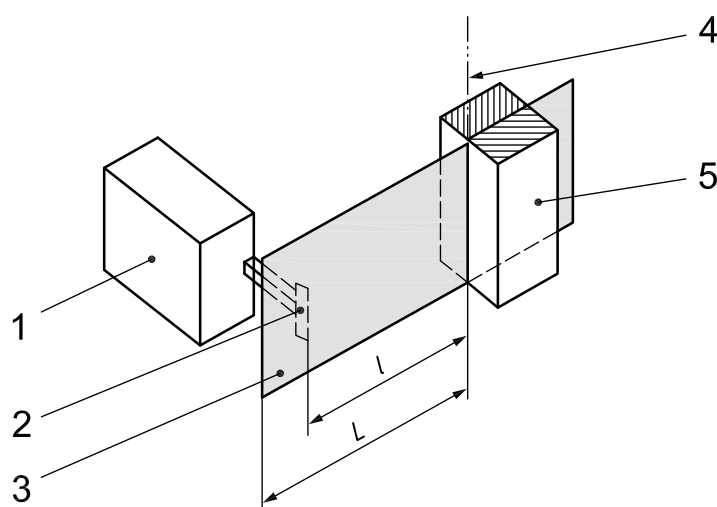


**5.2.2 Knife (2)**, mounted perpendicular to the initial movement of the test piece (3), applying a centrally placed bending force with respect to the width of the test piece.

The length of the knife edge is  $(16 \pm 2)$  mm and the edge is parallel to the pivoting axis (4) of the clamp. The edge is blunted and the distance from the edge to the pivoting axis of the clamp ( $l$ ) is  $(50,0 \pm 0,1)$  mm. If necessary, the distance from the edge to the pivoting axis of the clamp ( $l$ ) may be adjustable to  $(10,0 \pm 0,1)$  mm.

**5.2.3 Device for measuring the force (1)**, exerted on the knife edge by the test piece when it is bent through a bending angle of  $(15,0 \pm 0,3)^\circ$ , or if necessary  $(7,5 \pm 0,3)^\circ$  (see Clause 10). The accuracy of the force for readings from 0 mN to 100 mN shall be  $\pm 5\%$ , and for readings exceeding 100 mN it shall be  $\pm 2\%$ .

The movement of the sensor in its response direction shall be less than 0,05 mm over the full range of measurement. The force sensor has a low sensitivity to lateral forces.



#### Key

- |   |                                |     |                |
|---|--------------------------------|-----|----------------|
| 1 | device for measuring the force | $l$ | bending length |
| 2 | knife                          | $L$ | free length    |
| 3 | test piece                     |     |                |
| 4 | pivoting axis                  |     |                |
| 5 | clamp                          |     |                |

**Figure 1 — Sketch of the bending resistance testing**

## 6 Calibration

Calibrate the force sensor and the bending angle sufficiently frequently. The method of calibration depends on the type of instrument and reference should be made to the instrument manual.

## 7 Sampling

If the tests are being made to evaluate a lot, the sample shall be selected in accordance with ISO 186. If the tests are made on another type of sample, make sure that the specimens taken are representative of the sample received.

## 8 Conditioning

Condition the specimens of paper or board as specified in ISO 187. Carry out the preparation of test pieces and the testing in the same conditioning atmosphere as that used to condition the specimens.

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## 9 Preparation of test pieces

When testing the bending resistance in the machine direction or cross direction, the specified direction is perpendicular to the width of the test piece. Avoid folds, creases, visible cracks or other defects in the area to be tested. If watermarks are present in the test area, this shall be noted in the test report. Identify the sides of the specimens to ensure that an equal number of valid results are obtained with the force applied to each side.

Highly twisted and curled test pieces may give unreliable results. It is not possible to straighten curled or twisted samples without damaging the material.

Cut, in each required principal direction (machine direction and/or cross direction), a minimum of ten test pieces having the dimensions  $(38,0 \pm 0,2)$  mm wide and at least 80 mm long (50 mm bending length).

If the shorter bending length is used, the test pieces shall be at least 40 mm long (10 mm bending length).

## 10 Procedure

If the bending resistance index (3.6) is required, determine the grammage in accordance with ISO 536.

Carry out the test with a bending length of  $(50,0 \pm 0,1)$  mm. For samples having a bending resistance which is too low to be measured with a bending length of 50 mm, a shorter bending length of  $(10,0 \pm 0,1)$  mm may be used. If so, the bending length shall be reported.

**IMPORTANT — The results obtained using different bending lengths will not be comparable.**

Insert the test piece in the clamp, in such a manner that a given length of the test piece protrudes from the clamp and the test piece is correctly aligned. For the 50 mm bending length, this length ( $L$ ) is  $(57 \pm 3)$  mm; for the 10 mm bending length, this length ( $L$ ) is  $(17 \pm 3)$  mm. Do not touch the sample in the area near the clamp with bare hands. Altering the moisture content of this area can affect the measured result.

The clamping pressure shall be high enough to hold the test piece firmly, in such a way that the measured bending force is insensitive to the pressure (see Reference<sup>[6]</sup>).

Pneumatic or other means of ensuring that the pressure is controlled is recommended.

NOTE 1 Too high a pressure can result in lower bending-force values.

Set the instrument to a bending angle of  $15^\circ$ . Do not bend or flex the test piece in any way, prior to testing, and do not test any test piece more than once because continued flexing causes a progressive reduction of the bending force, thus causing a reduction of the bending resistance. In order to get a correct bending to a bending angle of  $15^\circ$  (or  $7,5^\circ$ ), make sure that the knife edge is in contact with the surface of the test piece, without applying any force on the test piece prior to the testing.

If the maximum force is obtained before the test piece has been bent through  $15^\circ$ , or a break, kink or crease is observed, the test result should be discarded. If more than 10 % of the test pieces exhibit this behaviour, use a bending angle of  $7,5^\circ$ . If so, the bending angle shall be reported.

**IMPORTANT — The result obtained at  $7,5^\circ$  cannot be converted to  $15^\circ$  by multiplying by two, since the relationship is not directly proportional to the bending angle.**

NOTE 2 The tendency for the paper to be deformed in an unacceptable way increases with increasing thickness. The exact thickness for using  $7,5^\circ$  cannot be stated.

Measure the bending force in the manner recommended in the instruction manual for the type of instrument used. Record the bending force (3.1),  $F$ , for the required number of test pieces.

When testing, equal numbers of valid results with opposing surfaces towards the direction of deflection shall be obtained. For each principal direction to be tested, a minimum of ten test pieces and ten valid readings are required for a given bending angle. No test piece shall be reused after it has been removed from the instrument clamp.

## 11 Calculation and expression of results

### 11.1 Bending resistance

For each required principal direction of test (machine direction and/or cross direction), calculate the bending resistance (3.2),  $B$ , as the mean of all valid bending-force readings,  $\bar{F}$ , and the standard deviation.

Report the bending resistance, for each required direction, in newtons or millinewtons, to three significant figures.

### 11.2 Bending resistance index

If required, calculate the bending resistance index (3.6) for each required principal direction of test (machine direction and/or cross direction) as follows:

$$B_1 = \frac{B}{g^3} \quad (1)$$

where

$B_1$  is the bending resistance index, in newtons times metres to the power of six per gram cubed ( $\text{N}\cdot\text{m}^6/\text{g}^3$ );

$B$  is the bending resistance, in newtons (N);

$g$  is the grammage, in grams per square metre ( $\text{g}/\text{m}^2$ ), determined in accordance with ISO 536.

Report the bending resistance index for each required principal direction to three significant figures.

**NOTE** The bending resistance index is strictly applicable for test pieces of homogeneous materials, bent through small angles. The bending resistance index is nevertheless useful for a comparison of the bending resistance of papers with small differences in grammage or normalizing the bending resistance to a given grammage. Bending to an angle of  $15^\circ$  usually means that there is a higher degree of plastic deformation of the test piece, the higher the grammage. For this reason, the bending resistance index is less useful for higher grammage material and less useful when papers with large differences in grammage are compared (see Reference<sup>[6]</sup>).

## 12 Test report

The test report shall include the following information:

- a) a reference to this part of ISO 2493, i.e. ISO 2493-1:2010;
- b) the date and place of testing;
- c) description and identification of the material tested;
- d) the conditioning atmosphere used;
- e) the bending angle, if it is not  $15^\circ$ ;
- f) the bending length, if it is not 50 mm;
- g) for each principal direction tested, the bending resistance, as specified in 11.1;
- h) for each principal direction tested, the standard deviation of the bending resistance;
- i) if required, for each principal direction tested, the bending resistance index, as specified in 11.2;
- j) any deviations from this part of ISO 2493 that may have affected the results.

## Annex A (informative)

### Precision

In November 2008, nine laboratories, from six European countries, tested six samples in the machine direction (MD) and cross direction (CD). For each sample, ten test pieces were tested, five using left bending and five using right bending.

The calculations were made according to ISO/TR 24498<sup>[3]</sup> and TAPPI T 1200<sup>[5]</sup>.

The repeatability standard deviation reported in Tables A.1 and A.2 is the “pooled” repeatability standard deviation, that is the standard deviation calculated as the root-mean-square of the standard deviations of the participating laboratories. This differs from the conventional definition of repeatability in ISO 5725<sup>[2]</sup>.

The repeatability and reproducibility limits reported are estimates of the maximum difference which should be expected in 19 of 20 instances, when comparing two test results for material similar to those described under similar test conditions. These estimates may not be valid for different materials or different test conditions.

Repeatability and reproducibility limits are calculated by multiplying the repeatability and reproducibility standard deviations by 2,77.

NOTE  $2,77 = 1,96\sqrt{2}$ , provided that the test results have a normal distribution and that the standard deviation  $s_r$  is based on a large number of tests.

**Table A.1 — Estimation of the repeatability of the test method**

Sample		Number of laboratories	Mean value	Standard deviation	Coefficient of variation	Repeatability limit
			mN	$s_r$ mN	CV %	$r$ mN
Coated unbleached carton board, 390 g/m <sup>2</sup>	MD	9	1 348	36,7	2,7	102
	CD	9	584	24,2	4,1	67,0
Kraftliner, 300 g/m <sup>2</sup>	MD	9	420	20,5	4,9	56,8
	CD	9	176	13,3	7,6	36,7
Solid bleached carton board, 220 g/m <sup>2</sup>	MD	9	152,6	12,4	8,1	34,2
	CD	9	79,7	8,9	11,2	24,8
Copy paper <sup>a</sup> , 80 g/m <sup>2</sup>	MD	9	100	10,0	10,0	27,7
	CD	9	48	6,9	14,4	19,2
Copy paper <sup>a</sup> , 75 g/m <sup>2</sup>	MD	9	135	11,6	8,6	32,2
	CD	9	43,1	6,56	15,2	18,2
Newsprint <sup>a</sup> , 45 g/m <sup>2</sup>	MD	9	28	5,3	18,9	14,7
	CD	8	7,0	2,6	37,1	7,3

<sup>a</sup> For samples of copy paper and newsprint, a bending length of 10 mm was used.

Table A.2 — Estimation of the reproducibility of the test method

Sample		Number of laboratories	Mean value	Standard deviation	Coefficient of variation	Reproducibility limit
			mN	$s_R$ mN	CV %	$R$ mN
Coated unbleached carton board, 390 g/m <sup>2</sup>	MD	9	1 348	82,2	6,1	228
	CD	9	584	52,7	9,0	146,2
Kraftliner, 300 g/m <sup>2</sup>	MD	9	420	27,9	6,6	77,4
	CD	9	176	15,7	8,9	43,6
Solid bleached carton board, 220 g/m <sup>2</sup>	MD	9	152,6	14,6	9,6	40,5
	CD	9	79,7	10,1	12,7	28,0
Copy paper <sup>a</sup> , 80 g/m <sup>2</sup>	MD	9	100	12,8	12,8	35,4
	CD	9	48	7,4	15,4	20,4
Copy paper <sup>a</sup> , 75 g/m <sup>2</sup>	MD	9	135	13,7	10,1	37,9
	CD	9	43,1	6,6	15,3	18,2
Newsprint <sup>a</sup> , 45 g/m <sup>2</sup>	MD	9	28	5,4	19,3	14,9
	CD	8	7,0	2,7	38,6	7,4

<sup>a</sup> For samples of copy paper and newsprint, a bending length of 10 mm was used.

## Bibliography

- [1] ISO 5628:1990, *Paper and board — Determination of bending stiffness by static methods — General principles*
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