
**Glass in building — Determination of
the bending strength of glass —**

**Part 3:
Test with specimen supported at two
points (four point bending)**

*Verre dans la construction — Détermination de la résistance du verre
à la flexion —*

*Partie 3: Essais avec éprouvettes supportées en deux points (flexion
quatre points)*



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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: [Foreword - Supplementary information](#)

The committee responsible for this document is ISO/TC 160, *Glass in building*, Subcommittee SC 2, *Use considerations*.

ISO 1288 consists of the following parts, under the general title *Glass in building — Determination of the bending strength of glass*:

- *Part 1: Fundamentals of testing glass*
- *Part 2: Coaxial double ring test on flat specimens with large test surface areas*
- *Part 3: Test with specimen supported at two points (four point bending)*
- *Part 4: Testing of channel shaped glass*
- *Part 5: Coaxial double ring test on flat specimens with small test surface areas*

Glass in building — Determination of the bending strength of glass —

Part 3:

Test with specimen supported at two points (four point bending)

1 Scope

This part of ISO 1288 specifies a method for determining the bending strength, including the effects of the edges, of flat glass for use in building. The method specified can also be used to determine the bending strength of the edges of glass separately.

The limitations of this part of ISO 1288 are described in ISO 1288-1.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 48, *Rubber, vulcanized or thermoplastic — Determination of hardness (hardness between 10 IRHD and 100 IRHD)*

ISO 1288-1, *Glass in building — Determination of the bending strength of glass — Part 1: Fundamentals of testing glass*

3 Terms and definitions

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

3.1

bending stress

tensile bending stress induced in the surface of a specimen

Note 1 to entry: For testing purposes, the bending stress should be uniform over a specified part of the surface.

3.2

effective bending stress

weighted average of the tensile bending stresses, calculated by applying a factor to take into account non-uniformity of the stress field

3.3

bending strength

bending stress or effective bending stress which leads to breakage of the specimen

3.4

equivalent bending strength

apparent bending strength of patterned glass, for which the irregularities in the thickness do not allow precise calculation of the bending stress

4 Symbols

B	specimen width	m
E	modulus of elasticity (Young's modulus) of the specimen	Pa
	NOTE For soda lime silicate glass (see ISO 16293-1), a value of 70 GPa is used.	
$F_{\max}$	maximum force	N
	NOTE Where the bending rollers are not firmly attached to the testing machine, but are laid on the specimen, the force resulting from their weight is added to the maximum measured force.	
g	acceleration due to gravity	m/s ²
h	specimen thickness	m
k	dimensionless factor (see ISO 1288-1:—, 6.2 for explanation)	
L	specimen length	m
L_s	distance between the centre lines of the supporting rollers	m
L_b	distance between the centre lines of the bending rollers	m
M_b	bending moment	Nm
y	central deflection of the specimen relative to the supporting rollers	m
Z	section modulus	m ³
σ_b	bending stress in the surface area defined by the bending rollers	Pa
σ_{beff}	effective bending stress	Pa
σ_{bB}	bending strength	Pa
σ_{bG}	bending stress imposed by the self-weight of the specimen	Pa
ρ	density of the specimen	kg/m ³

5 Apparatus

5.1 Testing machine

The bending test shall be carried out using a suitable bending testing machine, which shall incorporate the following features.

- The stressing of the specimen shall be capable of being applied from zero up to a maximum value in a manner which minimizes shock and is stepless.
- The stressing device shall be capable of the specified rate of stressing.
- The testing machine shall incorporate a load measuring device with a limit of error of $\pm 2,0$ % within the measuring range.
- The supporting rollers and the bending rollers (see [Figure 2](#)) shall have a diameter of 50 mm and a length of not less than 365 mm. All the rollers shall be free to rotate.

5.2 Measuring instruments

The following measuring instruments are required:

- a measuring instrument enabling the width of the specimen to be measured to the nearest 1 mm;
- a measuring instrument allowing the thickness of the specimen to be measured to the nearest 0,01 mm.

6 Sample

6.1 Number of specimens

The number of specimens to be tested shall be determined depending on the confidence limits required, especially with regard to estimating the extremes of the strength distribution (see ISO 1288-1 for a discussion of numbers of specimens).

6.2 Specimen dimensions

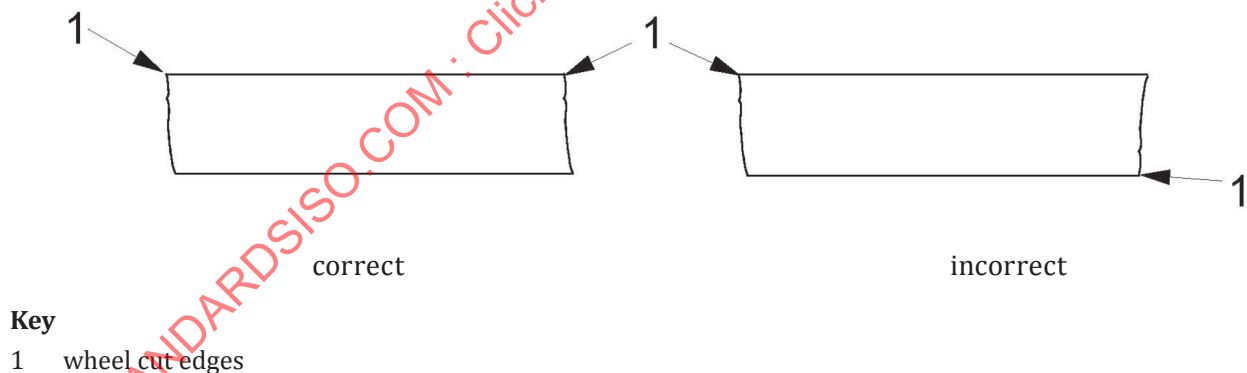
Specimen length L : 1 100 mm $\pm$ 5 mm

Specimen width B : 360 mm $\pm$ 5 mm

Specimen thickness h : thickness of the glass within the tolerance specified for the condition as supplied for test

6.3 Specimen condition and treatment

The specimens shall be flat and their edges shall be representative of the edge finish to be tested. If the edge is asymmetrical with respect to the neutral axis of the specimen, both stressed edges shall be in the same orientation (see [Figure 1](#)) and all specimens in a sample shall be tested the same way up.



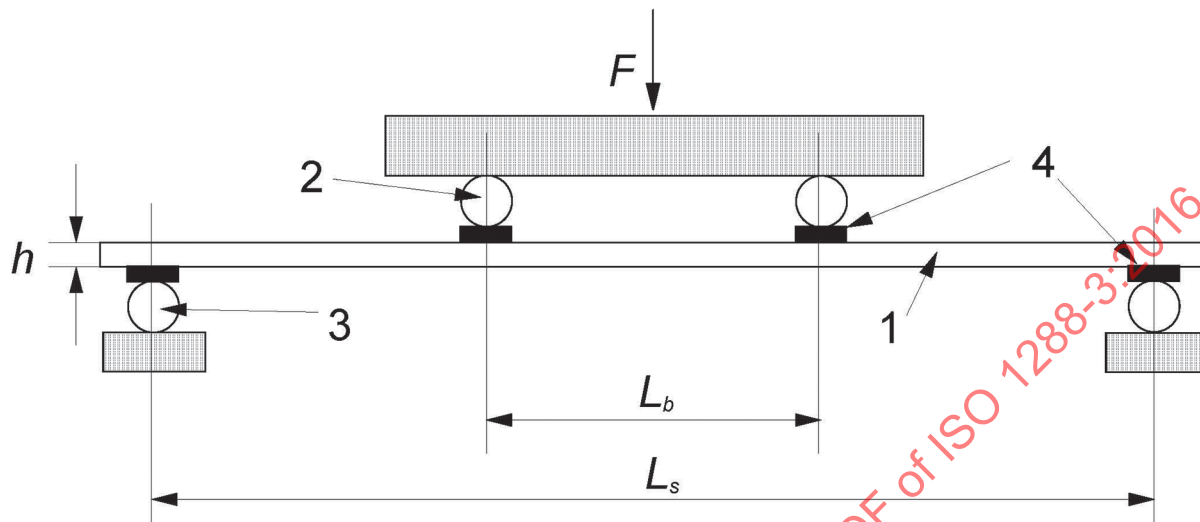
NOTE The edges of cut glass are not the same on both corners because wheel cut edges have the wheel applied to only one surface of the glass. In this instance, the edges are asymmetrical with respect to the neutral axis of the specimen.

Figure 1 — Asymmetrical edges

Any intended changes to the condition of the test piece by means of edge working, prior mechanical damage, etching, etc. shall be completed at least 24 h before testing the bending strength (see ISO 1288-1). Similarly, protective coatings shall be removed at least 24 h before the test. The specimens shall be stored in the testing environment (see [7.2](#)) for at least 4 h before being tested.

6.4 Adhesive film

To hold together the fragments, an adhesive film shall be fixed to the side of the specimens facing the bending rollers (see [Figure 2](#)). This facilitates location of the fracture origin and measurement of the specimen thickness.



Key

- 1 specimen
- 2 bending roller
- 3 supporting roller
- 4 rubber strips
- L_b 200 mm $\pm$ 1 mm
- L_s 1 000 mm $\pm$ 2 mm

Figure 2 — Mounting of the test specimen

7 Procedure

7.1 Measuring width and thickness of each specimen

The width shall be determined as the arithmetic mean of at least three individual measurements.

The thickness shall be determined as the arithmetic mean of at least four individual measurements to the nearest 0,05 mm. The measured positions shall lie outside the two bending rollers, to avoid damaging the test surface, and shall be taken from both ends of the specimen. In the case of specimens with one or two ornamental surfaces, both the plate thickness and core thickness shall be measured. The average is taken from all these measured values.

Alternatively, the thickness shall be determined from at least four fragments taken from the area between the bending rollers after fracture, if the fracture pattern makes this feasible.

7.2 Bending test

The specimen shall be mounted as shown in [Figure 2](#). Strips of rubber, 3 mm thick and of hardness (40 $\pm$ 10) IRHD (in accordance with ISO 48), shall be placed between the specimen and the bending and supporting rollers.

The bending test shall be carried out at $(23 \pm 5) ^\circ\text{C}$ with the relative humidity between 40 % and 70 %. During the test, the temperature shall be kept constant to $1 ^\circ\text{C}$ in order to avoid the development of thermal stresses.

The specimen shall be bent with a uniformly increasing bending stress at a rate of $(2 \pm 0,4) \text{ MPa/s}$ until failure occurs. The maximum load, F_{max} , shall be measured and the time taken to reach this load shall be recorded.

8 Evaluation

8.1 General

For evaluation purposes, only those specimens shall be considered in which the origin of fracture lies between the bending rollers.

The bending strength, σ_{bB} , shall be calculated in accordance with Formula (1) as follows.

For a rectangular cross section, where $Z = Bh^2/6$, and with the load applied as shown in [Figure 2](#), the bending strength is:

$$\sigma_{\text{bB}} = k \left[F_{\text{max}} \frac{3(L_s - L_b)}{2Bh^2} + \sigma_{\text{bG}} \right] \quad (1)$$

The bending stress, σ_{bG} , imposed by the self-weight of the specimen shall be calculated in accordance with Formula (2)

$$\sigma_{\text{bG}} = \frac{3\rho g L_s^2}{4h} \quad (2)$$

8.2 Bending strength of the surface area, edges included

For calculating the overall bending strength or equivalent bending strength of the surface area, including the edges, defined by the bending rollers, the value $k = k_s = 1$ shall be used (see ISO 1288-1).

8.3 Bending strength of the edges

For calculating the bending strength or equivalent bending strength of the free edges of the glass, only those specimens which fracture from the edge shall be taken into consideration.

NOTE When some of the specimens do not break from the edge, the set of edge strength results is not a true representation of the distribution of edge strengths. The edge strengths of those specimens which fracture from the test surface cannot be determined but they are certainly higher than the measured values of bending strength of such specimens. There are, however, statistical techniques which can make an allowance for the unmeasured edge strength of those specimens.

The factor $k = k_e$ for use in Formula (1) depends on the deflection of the specimen at its centre. The central deflection, y , can be determined by direct measurement or calculated with sufficient accuracy from Formula (3):

$$\frac{y}{h} = \frac{3F_{\text{max}}}{4EBh^4} \left[\frac{L_s^3}{3} + \frac{L_b^3}{6} - \frac{L_s L_b^2}{2} \right] \quad (3)$$

The appropriate value of k_e , for use in Formula (1), shall be obtained from [Figure 3](#), which gives the value of k_e as a function of the value of y/h (see ISO 1288-1).

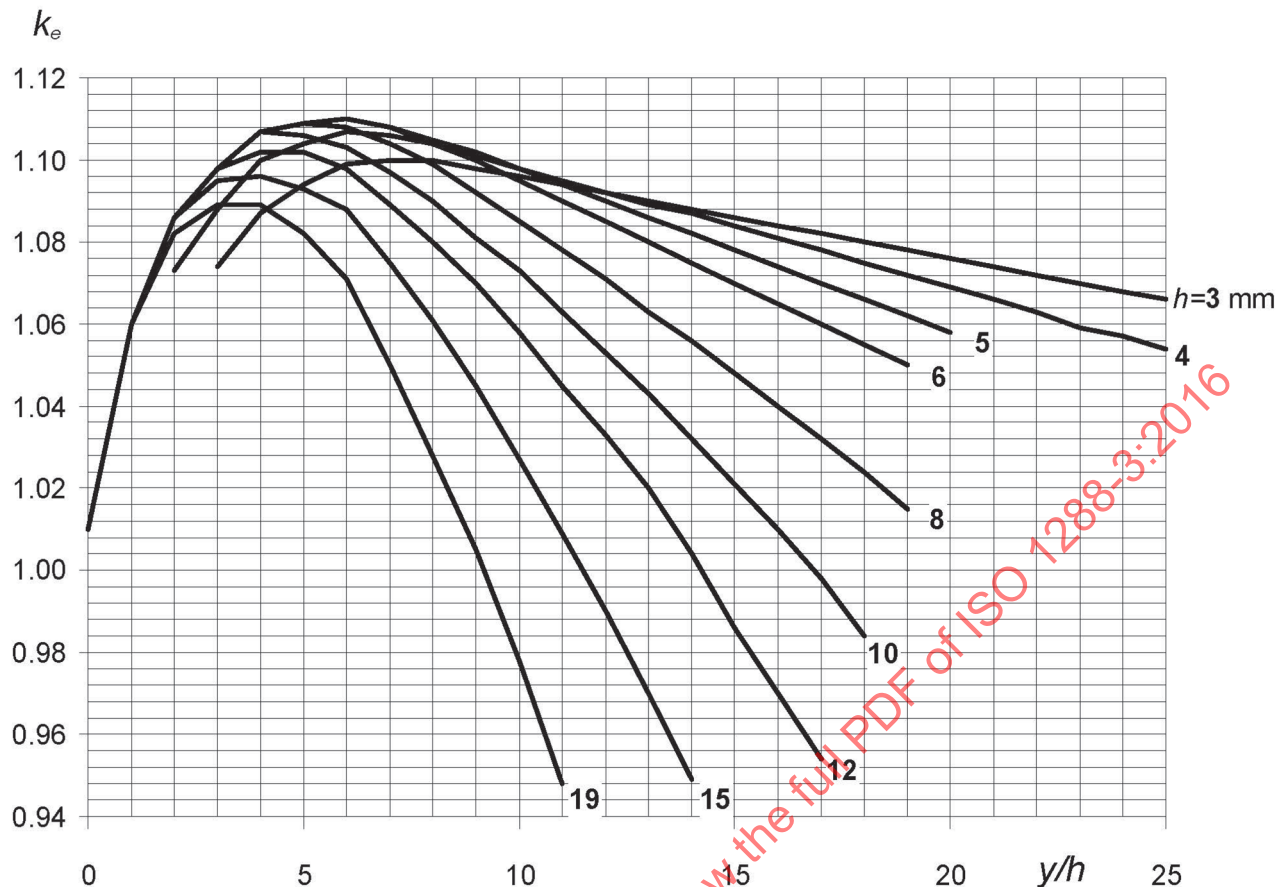


Figure 3 — Dimensionless factor k_e as a function of y/h

9 Test report

The test report shall include the following information:

- a) a reference to this part of ISO 1288, i.e. ISO 1288-3;
- b) type and name of glass;
- c) pre-treatment and surface condition of the tested specimen surface including the sequence of treatment stages. In the case of specimens with one patterned surface, the surface which is placed under tensile stress (flat or patterned side) shall be indicated;
- d) description of the edge finish and which way up it was tested;
- e) inherent stress of the specimen, annealed or prestressed glass, including nature and, if possible, degree of prestressing;
- f) number of specimens;
- g) for each specimen, the following information:
 - 1) thickness, h , in millimetres, to the nearest 0,05 mm, in the case of specimens with flat surfaces; maximum thickness (plate thickness), minimum thickness (core thickness) and average thickness, h , in millimetres, to the nearest 0,05 mm, in the case of specimens with one or two patterned surfaces;
 - 2) width in millimetres to the nearest 1 mm;

- 3) overall bending strength, σ_{bB} , or equivalent bending strength, σ_{beqB} , in MPa to the nearest 0,1 MPa;
- 4) if desired, edge bending strength, σ_{bB} , or equivalent bending strength, σ_{beqB} , in MPa to the nearest 0,1 MPa;
- 5) time to breakage in seconds to the nearest 1 s;
- 6) whether the specimen broke from the edge or the central part (body) of the specimen.

No average of the measured results shall be given;

- h) number of specimens not broken in accordance with [Clause 8](#);
- i) any deviation from this part of ISO 1288 which may have affected the results.

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