BRITISH STANDARD

BS EN
1288-5:2000

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

Part 5: Coaxial double ring test on flat specimens with small test surface areas

The European Standard EN 1288-5:2000 has the status of a British Standard

ICS 81.040.20

National foreword

This British Standard is the official English language version of EN 1288-5:2000.

The UK participation in its preparation was entrusted by Technical Committee B/520, Glass and glazing in building, to Subcommittee B/520/4, Properties and glazing methods, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

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Summary of pages

This document comprises a front cover, an inside front cover, the EN title page, pages 2 to 15 and a back cover.

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English version

Glass in building - Determination of the bending strength of glass - Part 5: Coaxial double ring test on flat specimens with small test surface areas

Verre dans la construction - Détermination de la résistance du verre à la flexion - Partie 5: Essais avec doubles anneaux concentriques sur éprouvettes planes, avec de petites surfaces de sollicitation

Glas im Bauwesen - Bestimmung der Biegefestigkeit von Glas - Teil 5: Doppelring-Biegeversuch an plattenförmigen Proben mit kleinen Prüfflächen

This European Standard was approved by CEN on 5 September 1999.

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This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat has the same status as the official versions.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
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EUROPÄISCHES KOMITEE FÜR NORMUNG

Central Secretariat: rue de Stassart, 36 B-1050 Brussels

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Contents

Foreword

This European Standard has been prepared by Technical Committee CEN/TC 129, Glass in building, the Secretariat of which is held by IBN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by December 2000, and conflicting national standards shall be withdrawn at the latest by December 2000.

CEN/TC 129/WG8, Mechanical Strength, prepared the draft, Glass in building - Determination of the bending strength of glass - Part 5: Coaxial double ring test on flat specimens with small test surface areas.

There are four other parts to this standard:

- 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.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

1 Scope

This European Standard specifies a method for determining the comparative bending strength of glass for use in buildings, excluding the effects of the edges.

NOTE: See 5.1.4 in EN 1288-1 for an explanation as to why this test method should only be used for comparing the strength of types of glass, and not for assessing strength for design purposes.

The limitations of this standard are described in EN 1288-1.

EN 1288-1 should be read in conjunction with this standard.

This test is not suitable for patterned glass.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references, the latest edition of the publication referred to applies.

EN 1288-1 Glass in building - Determination of the bending strength of glass - Part 1: Fundamentals of testing glass.
EN 572-1 Glass in building - Basic soda lime silicate glass products - Part 1: Definitions and general physical and mechanical properties.
ISO 48 Rubber, vulcanised or thermoplastic - Determination of hardness (hardness between 10 IRHD and 100 IRHD).

3 Definitions

For the purposes of this standard, the following definition applies.

3.1 bending stress: the tensile bending stress induced in the surface of a specimen

NOTE: For testing purposes, the bending stress should be uniform over a specified part of the surface.

4 Symbols

F Load

F_{max} Load at breakage, “breaking load”

h Thickness of specimen

L Side length of square specimens

K_1, K_2 Constants for calculation of bending stress

r_1 Radius of loading ring

r_2 Radius of supporting ring

r_3 Radius of circular specimens

r_{3m} Average specimen radius (for evaluation)

t Time

σ Stress

σ_{bB} Bending strength

μ Poisson number of specimen

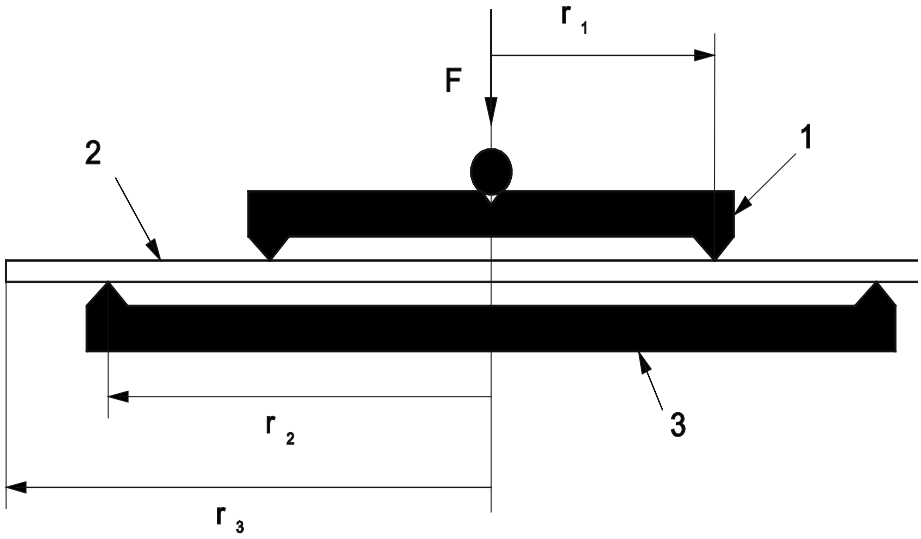
NOTE: For soda lime silicate glass (see EN 572-1), a value of 0,23 is used.

$\Delta F/\Delta t$ Rate of increase of load

$\Delta\sigma/\Delta t$ Rate of increase of stress

5 Principle of test method

A circular or square plane-parallel specimen with radius r_3, or length of side L, resting on a supporting ring (radius r_2) shall be loaded by means of a loading ring (radius r_1) arranged concentrically relative to the supporting ring (see Figure 1).



1 Loading ring
2 Specimen
3 Supporting ring

Figure 1: Test arrangement (indicating the principle), illustrated for a circular specimen

Outside the loading ring, the radial and tangential stresses in the specimen decrease towards the edge so that the risk of failure there is small.

For limited loads, F, (depending on the values of r_1, r_2, r_3 and h) there is, in the central region of the convexly bent specimen surface, a tensile stress field (see [1] in annex A) extending in all directions and uniform, the area in this field being bounded by the loading ring.

By increasing the load, F, the tensile stress in the middle of the specimen is increased at a constant rate until failure occurs, the expected point of failure being in the most severely stressed surface region defined by the loading ring.

The bending strength, σ_{bB}, shall be calculated from the maximum load, F_{max}, measured when failure occurs and the specimen thickness, h, taking into account the dimensions of the square or circular specimens and the value for Poisson number, μ, of the specimen.

6 Apparatus

6.1 Testing machine

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

a) 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.

b) The stressing device shall be capable of the specified rate of stressing.

c) The testing machine shall incorporate a load measuring device with a limit of error of ±2,0 % within the measuring range.

6.2 Loading device

The loading device shall be arranged as illustrated in Figure 2, with dimensions conforming to Table 1 for the two combinations of loading ring and supporting ring accepted for the coaxial double ring bending test. The radius ratio, r_1:r_2, shall be 1:5.

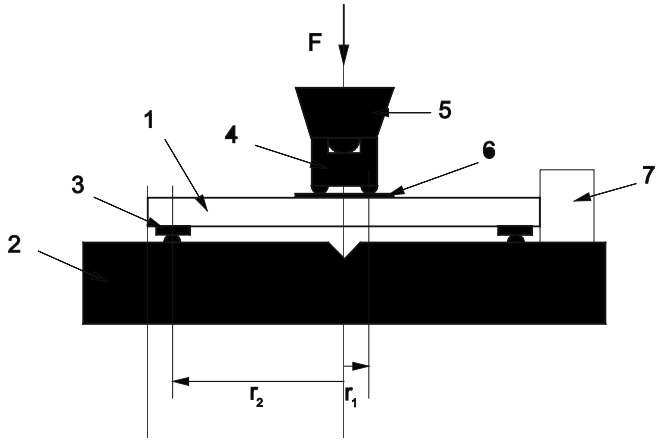
Table 1: Dimensions of loading ring and supporting ring

Loading device	Radius of loading ring, r_1 mm	Radius of supporting ring, r_2 mm	Radius r_3 or $L/2$ of specimen as specified in Table 2 mm
R45	9	45	50
R30	6	30	33

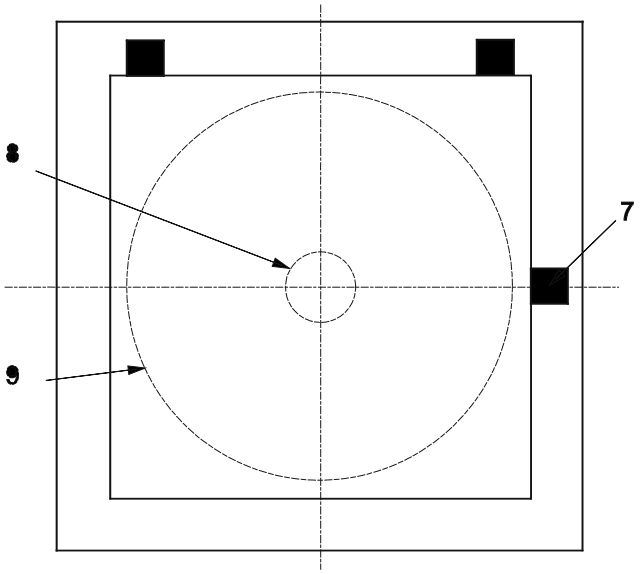
a) The radius of curvature of the bearing surface of the supporting ring shall be 2,5 mm;

b) The silicone rubber shall be 3 mm thick, or alternatively a rubber section, 3 mm thick, matched to the supporting ring with a hardness of (40 ± 10) IRHD, (according to ISO 48);

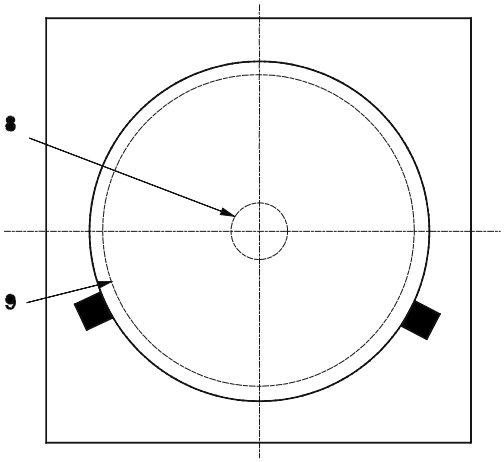
c) The radius of curvature of the bearing surface of the loading ring shall be 2,5 mm.



Cross-section



Square specimen



Circular specimen

1 Specimen
2 Base plate of hardened steel provided with a supporting ring
3 Spacer of silicone rubber
4 Loading ring of hardened steel
5 Load transmitting member with a centring feature for the loading ring
6 Spacer of paper or synthetic material approximately 0,1 mm thick
7 Adjusting jaw for centring the specimen
8 Contact circle of loading ring
9 Contact circle of supporting ring

Figure 2: Loading device

6.3 Measuring instruments

The following measuring instruments are required:

- a measuring instrument enabling the diameter or the length of the side of the specimen to be measured to the nearest millimetre;

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

7 Sample

7.1 Shape and dimensions of specimens

Circular or square specimens as specified in Table 2 and Table 3 shall be used.

Table 2: Dimensions of specimens

Loading device	Diameter (= $2r_3$) or side length L mm	Thickness h	
		minimum mm	maximum mm
R45	100 ± 2	see Table 3	9
R30	66 ± 2	see Table 3	6
NOTE: Within the limitations of Tables 2 and 3, the loading device R45 shall generally be selected.			

Table 3: Minimum thickness of specimens as a function of bending strength

Bending strength σ_{bB} N/mm^2	Minimum thickness of specimens for loading device	
	R45 mm	R30 mm
$\sigma_{bB} \leq 100$	2,0	1,0
$100 < \sigma_{bB} \leq 200$	2,5	1,5
$200 < \sigma_{bB} \leq 300$	3,0	2,0
$300 < \sigma_{bB} \leq 400$	3,5	2,5
$400 < \sigma_{bB} \leq 500$	3,5	2,5
$500 < \sigma_{bB} \leq 600$	4,0	3,0
NOTE: Within the limitations of Tables 2 and 3, the loading device R45 shall generally be selected.		

In cases in which not even the approximate value of the anticipated bending strength is known beforehand, the data given in the last line of Table 3 (values for bending strength up to 600 N/mm^2) shall be taken for the minimum thickness of the specimens. After the first tests have been evaluated, the appropriate minimum thickness shall be determined from Table 3.

The following tolerances shall apply to that portion of the specimen bounded by the contact circle of the supporting ring:

- the flatness tolerance shall be 0,1 mm;

- the parallelism tolerance shall be 2 % of the specimen thickness.

7.2 Sampling and preparation of specimens

7.2.1 Cutting and handling

The greatest care shall be taken that the test surface, which will be subsequently subjected to tensile stress, does not come into contact with tools, grinding agents, glass splinters, etc. and also is not damaged during storage.

NOTE 1: In order to preserve specific surface conditions, the test surface can be provided with a protective coating (glued down) during specimen preparation.

NOTE 2: The method of cutting specimens is not significant and no edge processing is necessary.

7.2.2 Conditioning

Protective coatings shall be removed 24 h before the test (see EN 1288-1). The specimen shall be stored in the test environment (see 8.1 and 8.2) for at least 4 h before testing.

7.2.3 Examination

Before the bending strength test, all specimens shall be examined over the test surface area for any faults which are not representative of the quality characteristics of the material tested.

7.2.4 Adhesive film

To hold together the fragments, an adhesive film shall be fixed to the side of the specimen facing the loading ring. This facilitates location of the fracture origin and measurement of the specimen thickness.

7.3 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 EN 1288-1 for a discussion of numbers of specimens).

8 Procedure

8.1 Temperature

The coaxial ring bending test shall be carried out at a temperature of (23 ± 5) ^{o}C. During the test, the temperature of the specimen shall be kept constant to 1 ^{o}C, in order to avoid the development of thermal stresses.

8.2 Humidity

The coaxial ring bending test shall be carried out at a relative humidity between 40 % and 70 %.

8.3 Thickness measurement

To prevent damage from being caused to the surface by measuring instruments, the thickness shall be measured at 4 points on the edge of the specimen. The average shall be taken from these measured values.

8.4 Base plate

The base plate is centred by moving down the force transmitting cone (without the loading ring and specimen) into the adjusting cone (see Figure 2). The base plate shall be locked in this position. Glass splinters and other hard and sharp-edged particles shall be cleaned from the supporting ring. Damage to the supporting ring shall be eliminated.

8.5 Positioning of specimen and loading ring

The silicone rubber spacer shall be positioned between the specimen and the base plate in such a way that, at each point, it protrudes beyond the bearing annulus on each side by not less than 5 mm. The specimen shall be placed in position with the surface to be tested downwards. The loading ring, which has been cleaned to remove splinters, shall then be lowered onto the top side of the specimen and centred, with the paper or synthetic spacer placed between the loading ring and the specimen (see Figure 2).

8.6 Load application

The test load, F, shall be increased in such a way that the bending stress in the middle of the specimen rises at a rate of (2 ± 0,4) N/mm^2·s until failure of the specimen occurs.

For calculating the rate of increase of the bending stress equation (1) shall be used for circular specimens and equation (2) for square specimens:

$$\frac{\Delta\sigma}{\Delta t} = \frac{K_1}{h^2} \cdot \frac{\Delta F}{\Delta t} \qquad (1)$$

$$\frac{\Delta\sigma}{\Delta t} = \frac{K_2}{h^2} \cdot \frac{\Delta F}{\Delta t} \qquad (2)$$

NOTE: The values of K_1 and K_2 depend on the Poisson number of the specimen. For soda lime silicate glass, the value of K_1 is 1,09 and the value of K_2 is 1,04 (see EN 1288-1).

The maximum load, F_{max}, shall be read from the load measuring device of the testing machine.

8.7 Location of the origin

The location of the origin of the fracture [A2] shall be determined from the fragments. The position of the origin of the fracture “inside or outside the contact circle of the loading ring” shall be determined for every specimen.

NOTE: After fracture, further thickness measurements, for control purposes, can be made on fragments from the centre of the specimen bounded by the loading ring contact circle, preferably as close to the fracture origin as possible.

8.8 Assessment of residual stresses

If the specimens are considered to be free from inherent stresses, (that is, they are of annealed glass), this condition shall be examined photo-elastically, in the case of transparent glasses, on specimens or suitable fragments. Stress-free specimens placed between cross-polarized polarizing filters shall not show any significant brightness variations when viewed through the cross-section over an optical path length of 5 mm.

9 Evaluation

9.1 Limitation of the evaluation

For evaluation purposes, only those specimens shall be considered in which the origin of the fracture lies within the area defined by the loading ring.

9.2 Calculation of bending strength

The bending strength, σ_{bB} associated with the maximum load F_{max} shall be calculated from equation (3) for circular specimens and from equation (4) for square specimens.

$$\sigma_{bB} = K_1 \frac{F_{max}}{h^2} \qquad (3)$$

$$\sigma_{bB} = K_2 \frac{F_{max}}{h^2} \qquad (4)$$

NOTE: The constants K_1 and K_2 apply for both loading device R45 and loading device R30 (see EN 1288-1).

10 Test report

The test report shall include the following information, with reference to this standard:

a) Type and name of glass;

b) Pre-treatment and condition of specimen surface including the sequence of treatment stages performed;

c) Inherent stress of the specimen, annealed or prestressed glass, including nature and if possible degree of prestressing;

d) Shape of specimens (circular or square);

e) Type of loading device (R45 or R30);

f) Number of specimens;

g) For each specimen, the following information:

1) Specimen thickness h, in mm to the nearest 0,05 mm;

2) Bending strength, σ_{bB}, in N/mm^2, rounded to the nearest 0,1 N/mm^2, of each specimen broken in accordance with 9.1;

3) Time to breakage in seconds to the nearest 1 s;

No average for the measured results shall be given;

h) Number of specimens not broken in accordance with 9.1;

i) Any deviation from this standard which may have affected the results.

Annex A (informative)

Bibliography

[1] Schmitt, R.W.; Blank, K.; Schönbrunn, G.: Experimentelle Spannungsanalyse zum Doppelringverfahren (Experimental stress analysis for the double ring method).

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