Bundesverband Flachglas

Fitness for purpose of linear-mounted glass

Fitness for purpose of linear-mounted glass

Table of Contents

1.0 Target group

This bulletin is intended for anyone planning, dimensioning, verifying, advising and/or making multi-pane insulating glass or monolithic glass panes and the associated linear mounting structures. They include planners, structural engineers, technical consultants, glass specialists and glass users.

2.0 Introduction

In the course of glass assessment according to DIN 18008 [1], verification of fitness for purpose always involves two fundamental questions:

- What are the deflection limit values to be assumed for the glazing unit, i.e. for the glass itself and the holding structure?
- What is the correlation between glass deflection and the durability of insulating glass?

The aim of the present bulletin is to answer these two questions by stating deflection limit values and explaining their correlation with the fitness for purpose of the insulating glass.

This bulletin does not replace the cited technical rules.

3.0 Application

This bulletin applies, in keeping with DIN 18008-2 [2][1], to plane, rectangular and infilling linear-mounted single-pane glass and insulating glass.

Infilling means that the glass panes are only stressed transversely to their plane, with the exception of their dead weight, which is supported in the plane too depending on the inclination. Linear-mounted means that a plane and continuous mounting of the glass edge on both sides (compression and suction) normal to the plane of the pane is achieved with mechanical connectors (e.g. glass bars or pressure bars) and is effective for all panes in the glass structure. The type of mounting approximates to Navier's plate theory boundary condition[2].

For point-mounted or for linear-mounted and point-mounted glass, see DIN 18008-3 [3][3]. For bonded glass, as used in all-glass structures or Structural Sealant Glazing systems, see ETAG 002 [4][4] or the associated system approvals.

4.0 Basic information

In accordance with DIN EN 1990 "Basis of structural design" [5][5], components must be planned and designed such that they meet the requirements set for fitness for purpose with appropriate reliability and efficiency during the intended duration of use. Verifications of fitness for purpose should[6] also deal with deformations and displacements that have a detrimental effect on the function of the structure, its appearance or the user's well-being.
They should also deal with those deformations and displacements that cause damage to non-load-bearing components, with a detrimental effect on durability.

Accordingly, DIN 18008-2 [2] defines deflection limit values for the glass[7] and the holding structure[8]. These apply however only to the function of the structure and are intended

- to comply with the application limits of structural calculation methods that require mounting of the glass in accordance with Navier's boundary condition and
- to ensure a sufficient glass mounting depth, so that the glass does not, even under stress, fall out of the holding structure.

DIN 18008-2 [2] explicitly[9] points out that glass manufacturers can require smaller deflections. This will be the case in particular for insulating glass when it has to be prevented that due to excessive deflections

- the durability of the insulating glass edge connection is reduced in terms of its diffusion tightness against steam and filler gases (avoidance of condensate, coating corrosion and filler gas losses to preserve the thermal insulation effect),
- the stability of the overall system is put at risk or
- contact between glass panes or with systems installed inside the cavity between the panes (e.g. bars or blinds) can occur.

It is also at the discretion of the planners to demand smaller deflections than specified in the standard, for example to avoid

- the occurrence of visual-aesthetic impairments, e.g. due to distortion of mirror images and
- the occurrence of large deflections due for example to wind gusts that can cause discomfort to the user or
- the occurrence of further impairments to use, for example water pooling in the case of glass installed horizontally or with a slight gradient.

All the stated protection aims / impairments can be described in terms of the deflection of the glass and the holding structure, and so complied with / limited respectively.

5.0 Definitions and symbols

5.1 Deflection and maximum deflection w_{max}

Deflection is the deformation of the glass transversely to its undeformed state. The maximum deflection w_{max} is the highest value for deflection. It occurs in the case of

- rectangular glass linear-mounted on four sides with a uniform surface load in the centre of the glass (cf. Figures 2a/2b and Figure 4),
- rectangular glass linear-mounted on two sides usually in the centre of the unmounted glass edge (cf. Figures 3a/3b).

With other mounting and load types, it can also occur outside, e.g. with linear mounting on three sides or with non-uniform or off-centre load due to a triangular surface load or an off-centre load from rails or blocks.

The maximum deflection w_{max} is the result of a glass structural calculation[10].

[1] Section 1, [2] Girkmann K. (1986): "Flächentragwerke", 6th edition, Springer-Verlag, Vienna, § 66 b), page 168, [3] section 8.2, [4] section 5.1.4.7,
[5] section 2.1 (1) second bullet, [6] section 3.4 (3), [7] sections 7.3 and 7.4, [8] section 4.3, [9] section 7.4, last sentence,
[10] The maximum deflection w_{max} corresponds to the design value for the effect E_d during verification in the limit state for fitness for purpose according to [1].

Fitness for purpose of linear-mounted glass

5.2 Deflections of glass and holding structure with linear mounting

5.2.1 Deflections of mounted glass edges or of holding structure

The deflections of the mounted glass edges match those of the holding structure. They also run transversely to the undeformed plane of the pane. Deflections with a different orientation or distortions of the holding structure are regarded as negligible. It is therefore assumed, in particular for insulating glass, that the supporting edge is ideally mounted at right angles to the undeformed plane of the pane (cf. Figure 1).

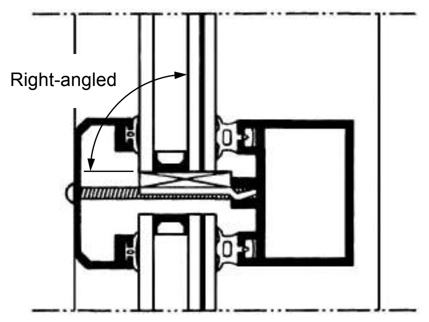

Figure 1: Supporting edge of insulating glass ideally mounted at right angles

5.2.2 Deflections of rectangular panes linear-mounted on four sides

Figures 2a and 2b show the deflection figures of rectangular panes linear-mounted on four sides. Figure 2a shows the deflection figure in a geometric linear calculation method. This is frequently applied in simplified form using so-called plate tables. However, it only supplies correct results when the maximum deflections are no larger than the glass thickness[11] ($w_{max} \leq$ glass thickness). With larger deflections, this calculation method overestimates the real deflections and main tensile stresses and can therefore deliver uneconomical glass thicknesses. Figure 2b shows the deflection figure in a geometric non-linear calculation method. This reproduces the real deflection behaviour also for deflections that exceed the glass thickness ($w_{max} >$ glass thickness). This calculation does require more complex solution methods (FEM or special plate tables), but delivers more economical glass thicknesses.

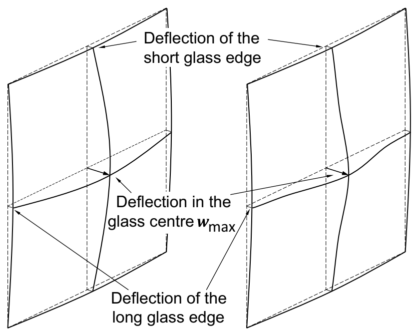

Figure 2a: Geometric linear calculation ($w_{max} \leq$ glass thickness)

Figure 2b: Geometric non-linear calculation ($w_{max} >$ glass thickness)

5.2.3 Deflections of rectangular panes linear-mounted on two sides

Figures 3a and 3b show the deflection figures of rectangular panes linear-mounted on two sides with geometric linear and with geometric non-linear calculation.

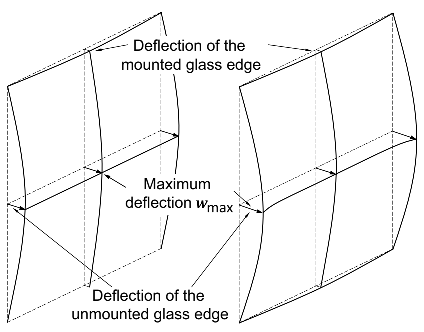

Figure 3a: Geometric linear calculation

Figure 3b: Geometric non-linear calculation

With this type of mounting, the results of the two calculation methods differ only slightly, however here too geometric non-linear calculation provides realistic deflections.

5.3 Reference length L

In DIN 18008-2 and in this bulletin, deflection limit values are not given as absolute quantities in mm, but are defined using the integer fraction of a reference length L (e.g. L/100).
A distinction must be made here between the reference length for the deflection of the mounted glass edge and the reference lengths for the deflection of the unmounted glass edge or glass centre.

5.3.1 Reference length for deflection of the mounted glass edge

For the mounted glass edge, the mounted pane length is used as the reference length L. It must not be confused with the frame, mullion or bar length of the substructure L_U, which can also be longer if, for example, several panes are mounted on one frame element (Figure 4). For the deflection limit values of substructures, see the appropriate component standards, e.g. DIN EN 14351-1 [8] for windows and doors, or DIN EN 13830 [9] for curtain walls.

5.3.2 Reference length for deflection of the unmounted glass edge or glass centre

For the unmounted glass edge and the glass centre, the span of the glass pane is used as the reference length L. The span is exactly defined only for linear-mounted rectangular panes and corresponds

- in the case of four-sided mounting to the length of the shorter glass edge (glass pane tensioned in two axes),
- in the case of three-sided mounting to the length of the unmounted glass edge and
- in the case of two-sided mounting to the spacing of the mounted glass edges (glass pane tensioned in one axis),

(cf. Figure 5).

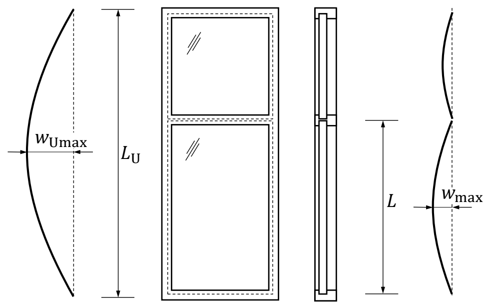

Figure 4: Reference length L of mounted panes in comparison with length of substructure L_U

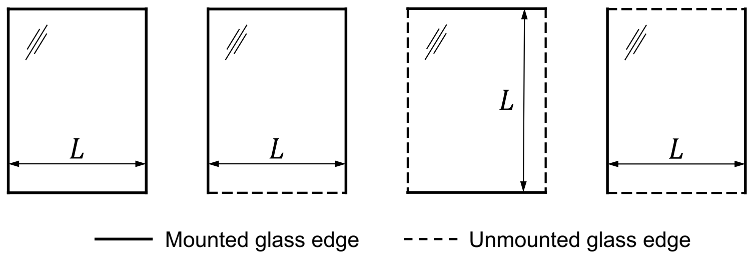

Figure 5: Span as reference length L of rectangular panes linear-mounted on four, three and two sides

[11] *In this case, the glass thickness of the individual pane considered is meant. For LG/LSG, that of the thinnest LG/LSG partial pane.*

Fitness for purpose of linear-mounted glass

5.4 Glass mounting depth i

The glass mounting depth i is determined in accordance with DIN 18545 [6][12] from the distance between the glass edge and the structurally effective edge of the holding structure (cf. Figure 6).
The glass mounting depth must, according to [2][13], be at least 10 mm at all glass edges, unless stipulations to the contrary have been made.

For insulating glass, the manufacturers are demanding, in line with [6][14], a larger minimum dimension of, as a rule, 12 mm, to protect the adhesives and sealants of the edge connection from UV radiation.

In the case of vertical panes, the glass mounting depth may also be smaller under load (see Section 5.5).

5.5 Chord shortening Δs

Chord shortening is the shortening of the distance between two opposite glass edges of a curved glass pane (cf. Figure 7).

Chord shortening of a glass panel linear-mounted on two sides is calculated approximately[15] from the maximum deflection w_{max} and the span L with

$$\Delta s \approx \frac{8}{3} \cdot \frac{w^2_{max}}{L}$$

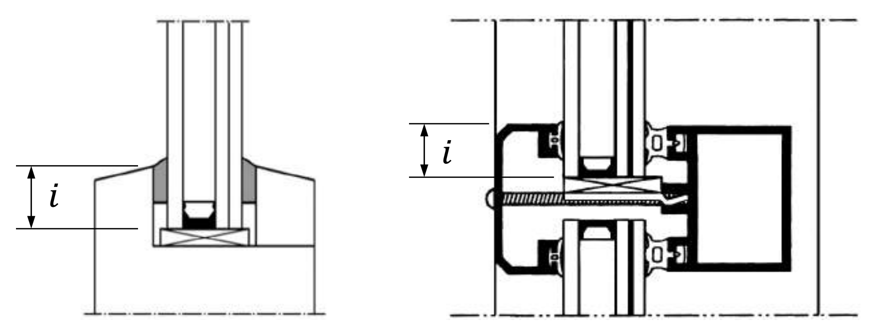

Figure 6: Glass mounting depth i, shown here at the supporting edge of insulating glass, left: window section, right: mullion/transom section

With linear mounting on four sides, the chord shortening is smaller, but is not so easy to calculate. For that reason, chord shortening in the linear mounting on two sides is used for simplification and to remain on the safe side.

According to DIN 18008-2 [2][16] , for vertical glazing the chord shortening or the deflection must be limited such that the remaining glass mounting depth at all glass edges is at least 5 mm, even if the entire chord shortening is applied to only one mounting. In this case, the deflection may also exceed L/100 or L/65 respectively (cf. Table 1).

The insulating glass manufacturer may however demand smaller chord shortenings or deflections, for example to limit the displacements in the edge connection (cf. Figure 8) or to protect systems inside the cavity.

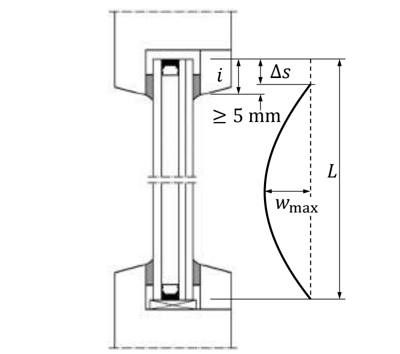

Figure 7: Chord shortening Δs,, maximum deflection w_{max}, reference length L and remaining glass mounting depth i – Δs ≥ 5 mm, shown here at the upper edge of insulating glass

[12] *Sections 4.1 and 4.2. Note: The European glazing standard DIN EN 12488 [7] defines "glass mounting depth" differently. The dimension i as defined according to [6] in the present document corresponds there to "mechanical edge coverage m".* [13] *section 4.1,* [14] *section 4,* [15] *derived at the arc with small opening angle by means of small-angle approximations* $\sin x \approx x - x^3/6$ *and* $\cos x \approx 1 - x^2/2$, [16] *section 7.4,* [17] *derived at the arc with small opening angle by means of small-angle approximation* $\cos \approx 1 - x2/2$, [18] *The deflection limit value* w_{perm} *corresponds to the design value for the fitness for purpose criterion* C_d *during verification in limit condition of fitness for purpose according to [1].* [19] *[2], section 7.4,* [20] *based on [10]*

5.6 Displacements in the edge connection in the case of a curved insulating glass edge

Figure 8 shows in a greatly exaggerated view the displacements v_1 and v_2 between glass and spacer in the edge area of the curved edge in a two-pane insulating glass unit (top). Additionally, the mutual displacement of the glass edges $v_1 + v_2$ and the resultant distortion of the adhesive/spacer flank is shown (bottom).

The displacements v_1 and v_2 are calculated approximately[17] with the glass thicknesses d_1 and d_2, the spacer height h, the maximum deflection w_{max} and the reference length L with

$$v_j \approx 2 \cdot (d_j + h) \cdot \frac{w_{max}}{L}, \quad j = 1.2.$$

Excessive displacements can lead to overstressing of the polymer sealants and of the spacer profile (including detachment from the glass surface) and hence to leakages reducing the durability of the overall system. This can result in condensation, coating corrosion, filler gas loss or reduction of the load-bearing capacity against forces acting on the edge connection (e.g. wind loads).

Particularly in the case of free insulating glass edges not mounted in a holding structure and hence unprotected from external weather effects, the displacements and the resultant distortions due to shear play a major role.
DIN 18008-2 [2] does not give any specific requirement for maximum deflection of the free insulating glass edge, but states the general limit value of L/100 for a rectangular pane mounted on four sides in the centre of the glass.

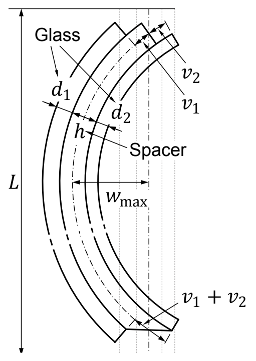

Figure 8: Displacements v_j between glass and spacer (top) and displacement of the glass edges (bottom) at the edge area of a curved insulating glass edge

The insulating glass manufacturer reserves the right to require for the unmounted insulating glass edge smaller deflections, e.g. L/200 (see Table 1).

6.0 Deflection limit values

DIN 18008 requires that glass be dimensioned such that the respective deflection limit value w_{perm} according to the following Table 1 is not exceeded[18].

Linear mounting	***Mounted glass edge*** (cf. Section 5.3.1)	***In glass centre***	***Unmounted glass edge***	
			Single-pane glass	***Insulating glass***
Two and three sides*	L/200	L/100**	L/100**	L/200***
Four sides			–	–

* In the case of linear mounting on three sides, it must be taken into account that, depending on the edge ratio, the maximum deflection is either in the glass centre or at the unmounted glass edge

** Unless there are visual-aesthetic or other requirements prohibiting it, for glass sizes
– up to max. 2 m^2 L/65 is also permissible
– for vertical glass an even greater deflection may be permissible, if the remaining glass mounting depth at all glass edges is at least 5 mm, even if the entire chord shortening is applied to only one mounting[19]

*** Recommendation of insulating glass manufacturers[20]

Table 1: Deflection limit value w_{perm} relative to the reference length

7.0 Verification

If the existing maximum deflection of the substructure (e.g. according to component standards [8] or [9]) and of the mounted glass edges acc. to Table 1 is permissible, fitness for purpose is verified in the following steps:

1. Determination of the reference length L depending on the glass mounting (on two, three, four sides).
2. Determination of the existing maximum glass deflection w_{max} and where it occurs (glass centre or glass edge) by means of glass structural calculation.
3. Determination of the deflection limit value w_{perm} according to Table 1, where necessary taking into account visual-aesthetic or other requirements.
4. Verification: $w_{max} \leq w_{perm}$
   If in the case of vertical glass the **footnote, second bullet of Table 1, is applied: Calculation of chord shortening Δs and verification of remaining glass mounting depth $i - \Delta s \geq 5$ mm.

8.0 Literature

[1] DIN 18008-1 (2010-12): Glass in building – design and construction rules – Part 1: Terms and general bases.

[2] DIN 18008-2 (2010-12 and amendment 1 dtd. 2011-04): Glass in building – design and construction rules – Part 2: Linearly supported glazings.

[3] DIN 18008-3 (2013-07): Glass in building – design and construction rules – Part 3: Point fixed glazing.

[4] ETAG 002 (2012-05): Structural Sealant Glazing Kits (SSGK) – Part 1: Supported and unsupported systems.

[5] DIN 1990 (2010-12 and amendment A1 dtd. 2012-08): Eurocode: Basis of structural design.

[6] DIN 18545 (2015-07): Sealing of glazing with sealants – Requirements for rebates and glazing systems.

[7] DIN EN 12488 (2016-11): Glass in building – Glazing recommendations – Assembly principles for vertical and sloping glazing.

[8] DIN EN 14351-1 (2016-12): Windows and doors – Product standard, performance characteristics – Part 1: Windows and external pedestrian doorsets.

[9] DIN EN 13830 (2015-07): Curtain walling – Product standard.

[10] Deutsches Institut für Bautechnik: Technical rules for the use of linear supported glazing (TRLV, 2006-08).

This Bulletin was produced by: Martin Reick (Flachglas MarkenKreis GmbH), Dr. Frank Ensslen (Semcoglas Holding GmbH) in the working group on 'insulating glass' at Bundesverband Flachglas e. V. · Mülheimer Strasse 1 · D-53840 Troisdorf

Bundesverband Flachglas e. V.
Mülheimer Strasse 1
D-53840 Troisdorf