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Contents
Fire-resistant façades - Statics - Building physics

* Deutsches Institut für Bautechnik = German Institute of Structural Engineering

** Technische Regeln für die Verwendung von linienförmig gelagerten Verglasungen
= technical rules for the application of in-line bedded glazings

*** Technische Regeln für die Verwendung von absturzsichernden Verglasungen
= technical rules for the application of crash-safe glazings

1. General indications

The present data and tables were drawn up according to the best of our knowledge and belief and are of use for the static predimensioning of façade elements. Load-bearing constructions and reinforcements must be stipulated in accordance with individual calculations. Before a contract is awarded the processing company must submit our suggestions and recommendations to a recognised structural engineer or the responsible architect for examination and have them accepted by the project owner.

2. Directives

2.1 Directive governing profiles with a thermal barrier issued by the DIBT (German Institute for Building Technology)

The "Directive Governing the Verification of the Stability of Metal Profiles with Thermal Barriers"[1] governs the assessment by the building supervisory authority of thermally insulated and thermally separated aluminium profiles with regard to their long-term stability. It is intended in particular for structural engineers and the building supervisory authority. Its validity is restricted to the main bearing members (supports, transoms etc.) of façades and window walls in accordance with DIN 18 056: 1966 – 06 with a width and/or height ≥ 2 m and a total area ≥ 9 m². It does not apply to components in up to two complete storeys and/or 8 m above height above ground or to floor-to-floor window elements at the back of terraces or balconies.

For profiles within the directive's scope, the system manufacturer must indicate the effective moments of inertia depending on the relevant distance between supports. As these take into account the influence of the composite parameters, this information always meets the directive's requirements. In accordance with the Conformity to Building and Construction Act[2] compliance with the directive is to be confirmed by a declaration of conformity by the system manufacturer on the basis of a general test certificate issued by the building supervisory authority.
Attention: With regard to static requirements must be pointed out that the indicated effective moments of inertia $I_{x, id}$ are based solely on a limitation of deflection of 1/300 of the distance between supports. This means that thermally separated aluminium profiles must conform to this limitation of deflection even if other regulations permit greater deflection (e.g. TRLV, see Chap. 3.2).

Pre-dimensioning by the metal window manufacturer is carried out as usual by means of the standard calculation method. In the directive's scope, the effective moments of inertia $I_{x, id}$ are used instead of the moments of inertia I_x depending on the distance between supports.

Verification by the structural engineer must be carried out in accordance with the "Draft directive for establishing and testing electronic stability verification". On request, the characteristics of the elastic composite established by an officially recognized authority will be made available by the system manufacturers to serve as dimensioning limits.

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1) The complete directive text has been published in the notifications of the German Institute for Building Technology no. 17 (1986), vol. 6, p. 197 ff.

2) The Conformity to Building and Construction Act applicable for the relevant case can be obtained from the publishers Ernst & Sohn, Bühringstraße 10, 13086 Berlin.

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2.2 Technical regulations regarding the use of in-line bedded glazing (TRLV) [3]

The regulations of the German Institute for Building Technologies apply to glazing which is bedded continuously in-line on at least two opposite sides. They apply to both vertical and overhead glazing. In accordance with the Conformity to Building and Construction Law, metal constructors must confirm compliance with these technical regulations by means of a certificate of conformity.
Along with requirements with regard to the dimensioning of individual panes limiting values for the deflection of the supporting structure are indicated: the deflection of supporting profiles must not exceed 1/200 of the supported pane length, with the maximum value being 15 mm.
However, the glazing guidelines issued by the insulating glass manufacturer may restrict the maximum deflection still further (e.g. 1/300 of pane length, max. 8 mm).

2.3 Technical regulations regarding the use of crash-safe glazing (TRAV) 4

The regulations of the German Institute for Building Technology apply to mechanically retained crash-safe glazing that secures a difference in altitude of more than 1 m. The static effects to be expected for the crash-safe glazing, such as wind load and beam load, are defined by DIN 1055. In case of insulating glass, climatic influences must be considered as well (see TRLV). In case of simultaneous wind load (w) and beam load (h), the least favourable of the two load combinations w + h/2 or h + w/2 may be taken as a reference load.
Mathematical proof of the bearing capacity is required for glazing and support construction.

2.4 Glazing guidelines - blocking

The glass loads are transmitted via setting blocks to the supporting construction. The number and position of the setting blocks depend on the type of glazing (opening sashes, fixed glazing). As a standard, the distance between the setting blocks and the glass corner is 100 mm. For fixed glazing and transoms with a wide span, it can be particularly advisable to shift the position of the setting blocks in the direction of the glass corner in order to limit transom deflection.
Because the glass breakage risk can be increased depending on the type of glass, it is absolutely necessary to co-ordinate measures of this kind beforehand with the glass manufacturer.

3. Static pre-dimensioning

3.1 Coordinates system

In contrast to the definition in DIN 1080 - 1, the following coordinate system is used in the present documents:

3.2 Determination of the required moment of inertia I_x

As with any other structural component of a building, glass-bearing aluminium constructions must be sufficiently dimensioned with regard to statics. For this purpose it must be ensured that the profiles used do not exceed the maximum permissible deformations in the case of wind load, or, where applicable, impact stress (beam load).

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3) The "Technical regulations regarding the use of in-line bedded glazing" have been published in the notifications of the DIBt 6/1998 and can be obtained from the publishers Ernst & Sohn, Bühringstraße 10, 13086. The complete text, with extensive explanations, can also be found in: i.f.t Rosenheim (ed.); i.f.t forum 1/00 Linienförmig gelagerte Verglasungen [In-line bedded glazing]; Rosenheim 1999.

4) The "Technical regulations regarding the use of crash-safe glazing – draft of March 2001" have been published in the notification of the DIBt of 3/2001 which can be obtained from the publishers Ernst & Sohn, Bühringstraße 10, 13086.

4 Mullion selection

The ETB (introduced technical structural stipulations) guideline on "Elements that safeguard against crash-in" calls for housing of a line load **p** at a height of 0.9 m above the floor.
It differentiates between 2 installation areas in respect of the height of the line load: in installation area 1 (areas with smaller gatherings of people, e.g. offices) this amounts to 0.5 kN/m, … installation area 2 (areas with greater gatherings of people, e.g. assembly rooms) 1.0 kN/m. The linear distributed load always acts from the interior of the building if the wind develops simultaneously. It can otherwise develop from both sides.

Wind loads arise in addition to this. These have to be superimposed with this load in accordance with the ETB guideline. As it is unlikely that both loads will arise at the same time, the dimensioning combinations **p + 0.5 w** (p = linear distributed load, w = wind load) and **0.5 p + w** are usually formed and the worst value drawn on for dimensioning.
The wind load **w** is calculated from the decisive dynamic pressure **q** against the height above the ground level and the pressure factor cp.

Height above ground level	Dynamic pressure q [kN/m²]
0 – 8	0.5
> 8 – 20	0.8

The pressure factors differ depending on the pressure or suction impact of the dynamic pressure.
Increased suction loads are to be applied in the peripheral range of buildings.

Range	cp suction [ ]	cp pressure [ ]
Normal range	0.5 – 0.7	0.8 x 1.25
Peripheral range	2,0	0.8 x 1.25

According to the ETB guideline the soft impact of a 50 kg crystal ball in a sack serves to substantiate the dynamic load as a result of impact loads by the human body.

Any possible thinness of walls and buckling of the sections arising from this are taken into account during dimensioning.

The ETB guideline does not expressly ask for proof of the suitability for use. Fire-resistant glazing must, however, satisfy a deflection restriction of H/200 in order to obtain a general approval from the building supervisory authority. The "technical rules for the use of in-line bedded glazing" also ask for a restriction of the deflection of the supporting profiles to L/200 so that the deflection is restricted to this value.

Evidence of the stability is provided as a stress analysis according to the second order theory on the basic approach of imperfections (rod pre-bending L/200) and under 1.7-fold loads against arriving at the 0.2% yield point.
In this connection the dead weight of the construction is taken into account at 120 kg/m².

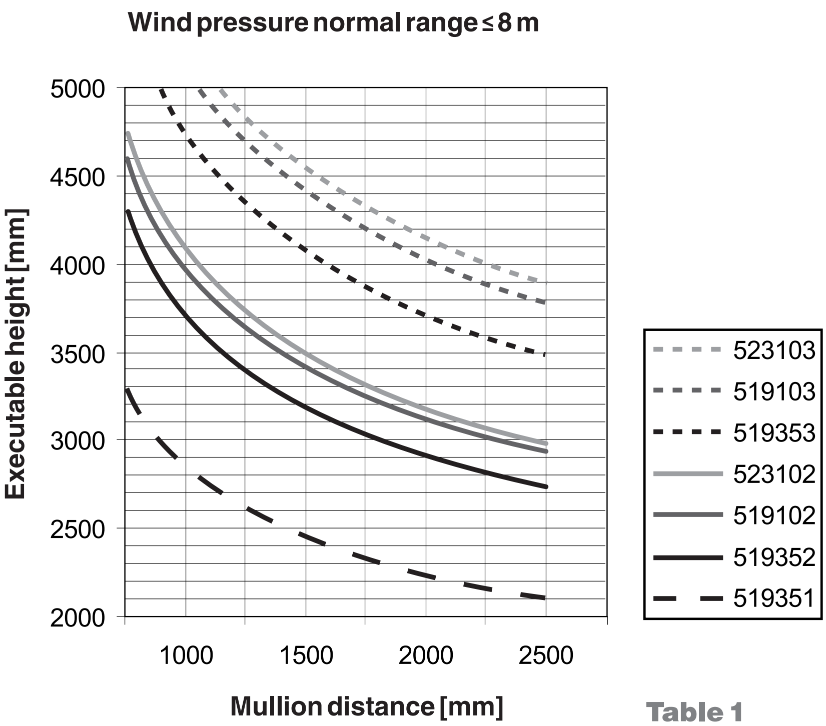

Table 1

Wall heights ≤ 8 m above top ground level
Dynamic pressure q = 0.5 kN/m²
Wind pressure factor cd = 0.8 x 1.25
Wind pressure factor cs = 0.7
Linear distributed load q = 1.0 kN/m²

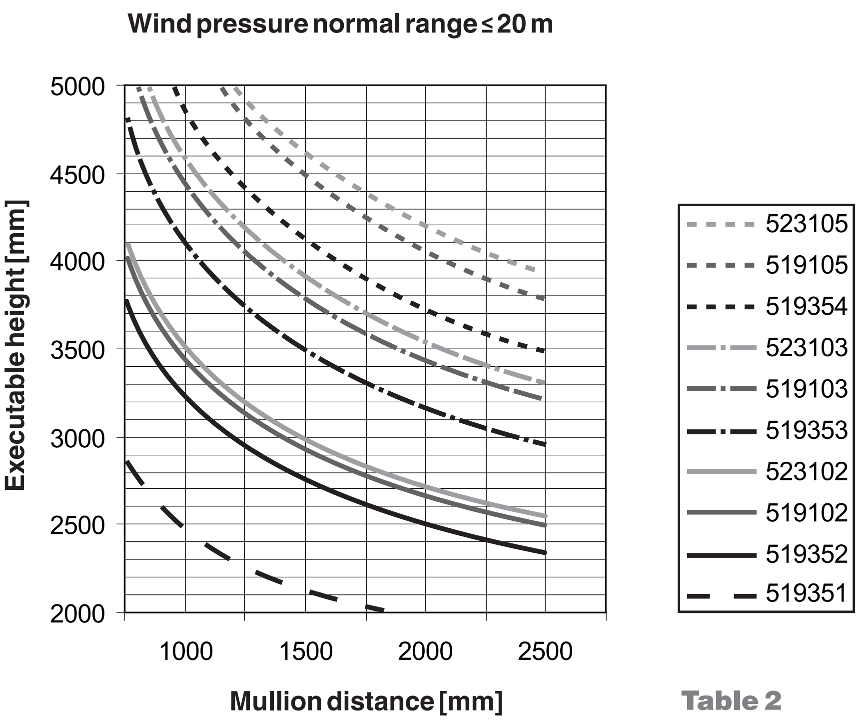

Table 2

Wall heights ≤ 20 m above top ground level
Dynamic pressure q = 0.8 kN/m²
Wind pressure factor cd = 0.8 x 1.25
Wind pressure factor cs = 0.7
Linear distributed load q = 1.0 kN/m²

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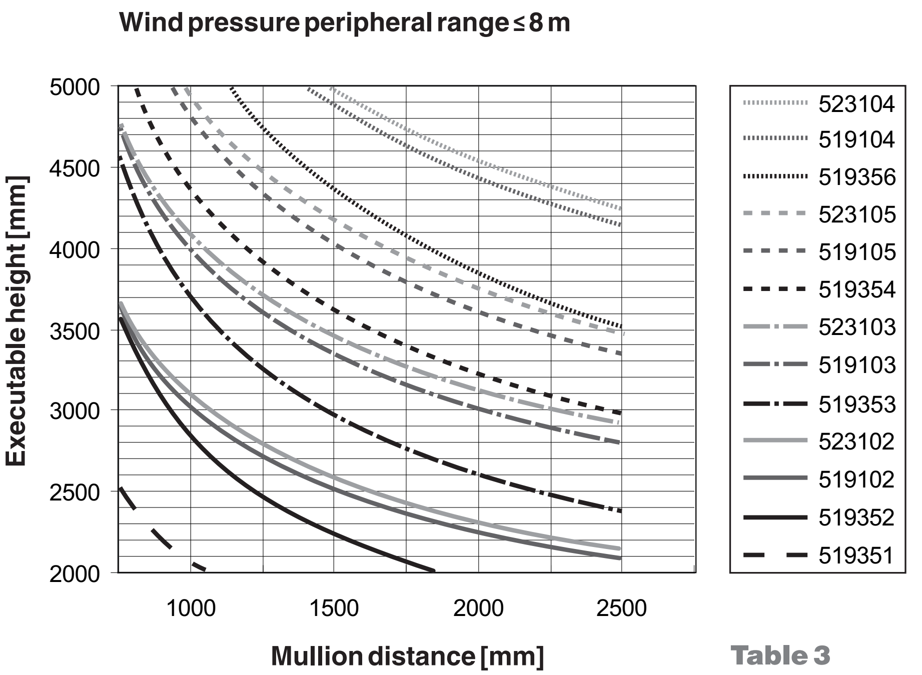

Table 3

Wall heights ≤ 8 m above top ground level
Dynamic pressure q = 0.5 kN/m²
Wind pressure factor cd = 0.8 x 1.25
Wind pressure factor cs = 2
Linear distributed load q = 1.0 kN/m²

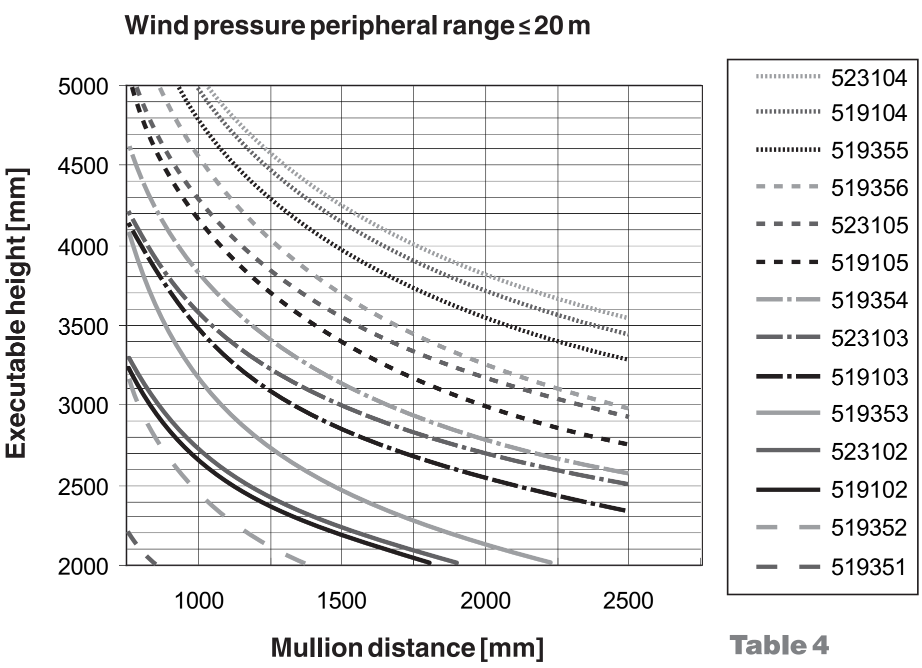

Table 4

Wall heights ≤ 20 m above top ground level
Dynamic pressure q = 0.8 kN/m²
Wind pressure factor cd = 0.8 x 1.25
Wind pressure factor cs = 2
Linear distributed load q = 1.0 kN/m²

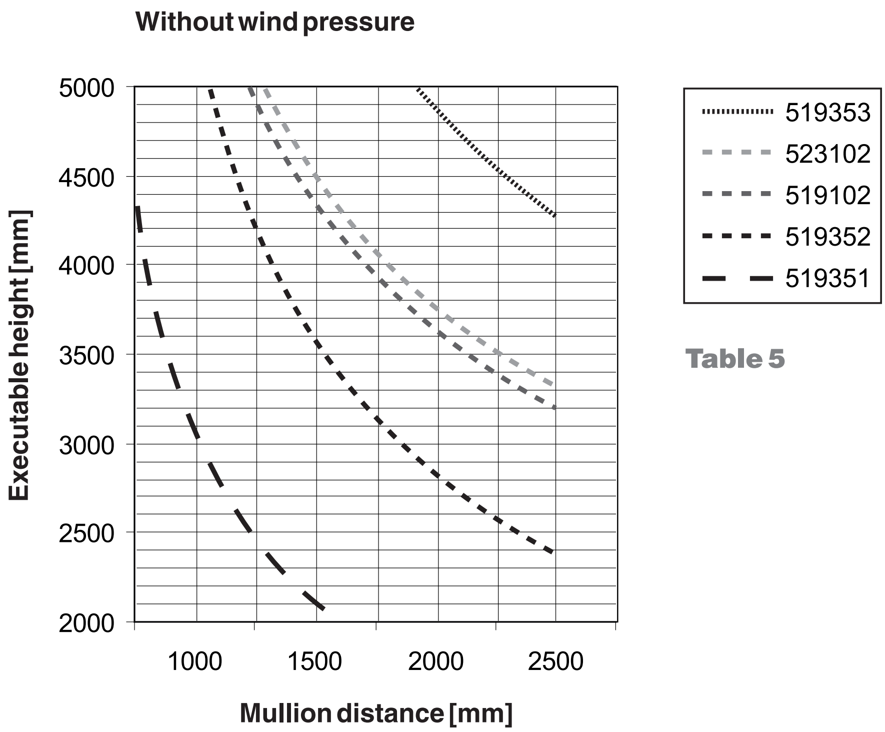

Table 5

Dynamic pressure q = 0
Wind pressure factor cd = 0
Wind pressure factor cs = 0
Linear distributed load q = 1.0 kN/m²

5 Transom selection

5.1 relating to horizontal occurrence of forces

Type of load 1: Transom as beam at height of 1 m
with linear distributed load = 1 kN/m²
(le = 1200 mm) (worst load assumption)

Type of load 2: Transom between 2 panes
without linear distributed load
(le= 1400 mm) (worst load assumption)

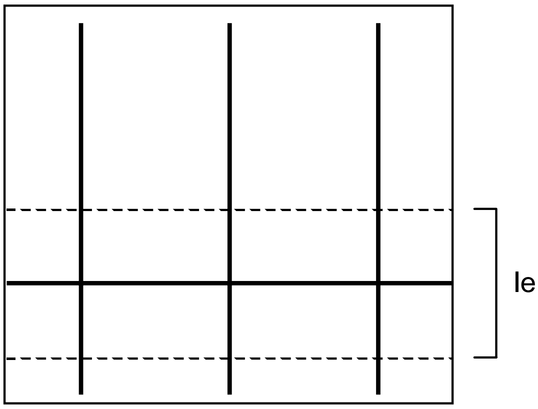

Table 6

Wind pressure normal range up to installation height 8 m		Maximum mullion distance	
		Type of load 1	Type of load 2
VF50	519 301	max. 2500 mm	max. 2500 mm
	519 302	max. 2500 mm	max. 2500 mm
	519 303	max. 2500 mm	max. 2500 mm
VF50RR	519 351	max. 2500 mm	max. 2500 mm
	519 352	max. 2500 mm	max. 2500 mm
	519 353	max. 2500 mm	max. 2500 mm
	519 354	max. 2500 mm	max. 2500 mm
	519 355	max. 2500 mm	max. 2500 mm
	519 356	max. 2500 mm	max. 2500 mm
VF60	523 301	max. 2500 mm	max. 2500 mm
	523 302	max. 2500 mm	max. 2500 mm
	523 303	max. 2500 mm	max. 2500 mm

Wall heights ≤ 8 m above top ground level
Dynamic pressure q = 0.5 kN/m²
Wind pressure factor cd = 0.8 x 1.25
Wind pressure factor cs = 0.7

Table 7

Wind pressure normal range up to installation height 20 m		Maximum mullion distance	
		Type of load 1	Type of load 2
VF50	519 301	max. 2350 mm	max. 2250 mm
	519 302	max. 2500 mm	max. 2500 mm
	519 303	max. 2500 mm	max. 2500 mm
VF50RR	519 351	max. 2350 mm	max. 2250 mm
	519 352	max. 2500 mm	max. 2500 mm
	519 353	max. 2500 mm	max. 2500 mm
	519 354	max. 2500 mm	max. 2500 mm
	519 355	max. 2500 mm	max. 2500 mm
	519 356	max. 2500 mm	max. 2500 mm
VF60	523 301	max. 2450 mm	max. 2350 mm
	523 302	max. 2500 mm	max. 2500 mm
	523 303	max. 2500 mm	max. 2500 mm

Wall heights ≤ 20 m above top ground level
Dynamic pressure q = 0.8 kN/m²
Wind pressure factor cd = 0.8 x 1.25
Wind pressure factor cs = 0.7

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Table 8

Wind pressure peripheral range up to installation height 8 m		Maximum mullion distance	
		Type of load 1	Type of load 2
VF50	519 301	max. 1950 mm	max. 2100 mm
	519 302	max. 2500 mm	max. 2500 mm
	519 303	max. 2500 mm	max. 2500 mm
VF50RR	519 351	max. 1950 mm	max. 2100 mm
	519 352	max. 2500 mm	max. 2500 mm
	519 353	max. 2500 mm	max. 2500 mm
	519 354	max. 2500 mm	max. 2500 mm
	519 355	max. 2500 mm	max. 2500 mm
	519 356	max. 2500 mm	max. 2500 mm
VF60	523 301	max. 2050 mm	max. 2150 mm
	523 302	max. 2500 mm	max. 2500 mm
	523 303	max. 2500 mm	max. 2500 mm

Wall heights ≤ 8 m above top ground level
Dynamic pressure q = 0.5 kN/m²
Wind pressure factor cd = 0.8 x 1.25
Wind pressure factor cs = 2

Table 9

Wind pressure peripheral range up to installation height 20 m		Maximum mullion distance	
		Type of load 1	Type of load 2
VF50	519 301	max. 1750 mm	max. 1800 mm
	519 302	max. 2250 mm	max. 2300 mm
	519 303	max. 2500 mm	max. 2500 mm
VF50RR	519 351	max. 1750 mm	max. 1800 mm
	519 352	max. 2250 mm	max. 2300 mm
	519 353	max. 2500 mm	max. 2500 mm
	519 354	max. 2500 mm	max. 2500 mm
	519 355	max. 2500 mm	max. 2500 mm
	519 356	max. 2500 mm	max. 2500 mm
VF60	523 301	max. 1800 mm	max. 1850 mm
	523 302	max. 2350 mm	max. 2350 mm
	523 303	max. 2500 mm	max. 2500 mm

Wall heights ≤ 20 m above top ground level
Dynamic pressure q = 0.8 kN/m²
Wind pressure factor cd = 0.8 x 1.25
Wind pressure factor cs = 2

Table 10

Without wind pressure		Maximum mullion distance
		Type of load 1
VF50	519 301	max. 1950 mm
	519 302	max. 2500 mm
	519 303	max. 2500 mm
VF50RR	519 351	max. 1950 mm
	519 352	max. 2500 mm
	519 353	max. 2500 mm
	519 354	max. 2500 mm
	519 355	max. 2500 mm
	519 356	max. 2500 mm
VF60	523 301	max. 2050 mm
	523 302	max. 2500 mm
	523 303	max. 2500 mm

Dynamic pressure q = 0 kN/m²
Wind pressure factor cd = 0
Wind pressure factor cs = 0

In the case of unequal mullion distances the average value to the neighbouring mullions must not exceed the admissible mullion distance.

5.2 Determination of required moments of inertia based on transom deflection

The maximum transom deflection is limited to 3 mm.
Deflection is calculated using equation (1) which does not consider the transom's dead weight.

$$I_{y,\,req} = \frac{\frac{G}{2} \cdot a \cdot (3l^2 - 4a^2)}{24 \cdot E \cdot f} \qquad (1)$$

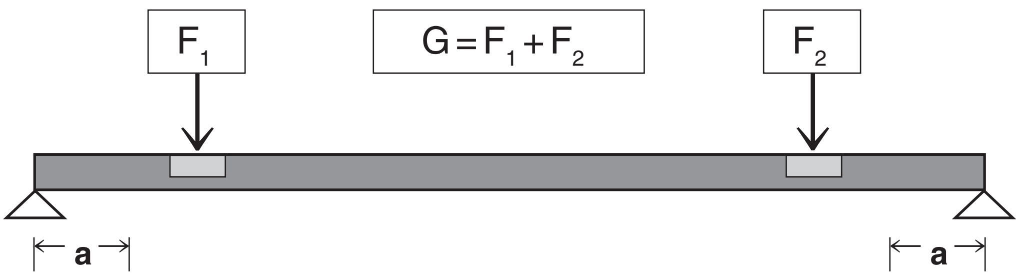
G Force of insert element
a Distance between centre of setting block and transom edge
l Transom length
E Modulus of elasticity aluminium (7000 kN/cm²)
f Transom deflection
(3 mm in accordance with product standard)

The equation can be resolved as follows:

$$\frac{I_{y,req}}{G} = \frac{a \cdot (3l^2 - 4a^2)}{2 \cdot 24 \cdot E \cdot f} \qquad (2)$$

The illustration below shows the equation for three variants:

a = 150 mm corresponds to 100 mm distance between the setting block and the glass corner, in accordance with standard glazing guidelines



If the distance between the setting block and the glass corner is less than 100 mm, blocking requires individual authorization by the glazing industry.
However, the consent of the glass manufacturer must be obtained in any case.

Diagram 1

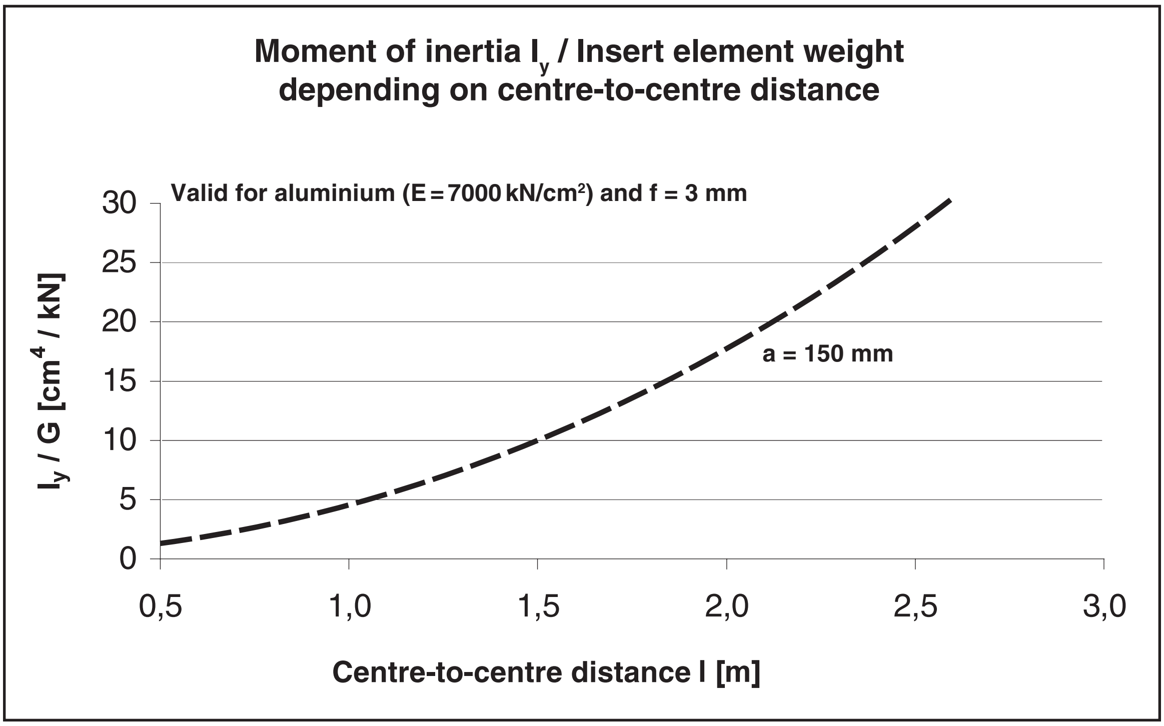


Diagram 1 enable the following values to be determined:

1. Required: permissible centre-to-centre distance
Given: moment of inertia and insert element weight

$$\text{adm. transom length } [m] = \text{reading value} \left(\frac{I_{y\,ex.}}{G_{ex.}} \; \frac{cm^4}{kN} \right)$$

2. Required: permissible insert element weight
Given: moment of inertia and centre-to-centre distance

$$G_{perm.}\,[kN] = \frac{I_{y\,ex.}\,[cm^4]}{\text{reading value}\left(\frac{l}{G}\right)}$$

3. Required: permissible moment of inertia
Given: insert element weight and centre-to-centre distance

$$I_{y\,req.}\,[cm^4] = \text{reading value}\left(\frac{l}{G}\right) \cdot G_{ex.}\,[kN]$$

$I_{y\,ex.}$ Existing moment of inertia of transom

$I_{y\,req.}$ Required moment of inertia of transom

$G_{ex.}$ Existing insert element weight

$G_{perm.}$ Permitted insert element weight

6. T-joints

The T-joints between mullions and transoms of the BSC VF50RR, BSC VF50 and BSC VF60 series were proven.

Positive evidence was provided for all T-joints for pane formats up to 1.4 m x 2.4 m, vertical and horizontal, as well as for a maximum installation height of 20 m and an overall maximum pane weight of 195 kg.

Glazing possibilities:

Fire-resistant glazing for fire-resistance class F30 according to DIN 4102-13.
Max. pane size 1400 x 2400mm.

Type:	Thickness	Max. weight	Weight / m²
Pyrostop – Type 30-1…	15 (17) mm	117.6 kg	35 kg/m²
Pyrostop – Type 30-17…	32 (36) mm	191.5 kg	57 kg/m²
Pyrostop – Type 30-20 …	18 mm	151.2 kg	45 kg/m²
Pyrostop – Type 30-2 …	32 (36) mm	194.9 kg	58 kg/m²
Pyrostop – Type 30-27 …	35 (39) mm	218.4 kg	65 kg/m²
Pyrostop – Type 30-3 …	32 (36) mm	194.9 kg	58 kg/m²
Promaglas 30, Type 1 …	17 mm	134.4 kg	40 kg/m²
Promaglas 30, Type 2 …	21 (22) mm	168.0 kg	50 kg/m²
Promaglas 30, Type 3 …	35 mm	215.1 kg	64 kg/m²
Promaglas 30, Type 5 …	17 mm	127.7 kg	38 kg/m²
Promaglas 30, Type 6 …	30 mm	174.7 kg	52 kg/m²
Promaglas 30, Type 10 …	21 mm	154.6 kg	46 kg/m²

Fire-resistant glazing for fire-resistance class G30 according to DIN 4102-13.
Max. pane size 1200 x 2300mm.

Type:	Thickness	Max. weight	Weight / m²
Pyrodur – Type 30-201…	10 mm	66.2 kg	24 kg/m²
Pyrodur – Type 30-28 …	31 (35) mm	146.3 kg	53 kg/m²
Pyrodur – Type 30-2 …	28 (32) mm	132.5 kg	48 kg/m²
Pyrodur – Type 30-3 …	28 (32) mm	132.5 kg	48 kg/m²

Please also be sure to read the attachments 18ff to approvals Z-70.4-110 and Z-70.4-111.
The glass thicknesses and glass weights are to be confirmed and checked.

7. Glass retainer

The following maximum filling weight per field must not be exceeded, i.e. per 2 glass retainers:

VF50RR • VF50:

913 382 for 16 mm rebate: 236 kg
913 384 for 22 mm rebate: 226 kg
913 340 for 32 mm rebate: 209 kg
913 270 for 42 mm rebate: 200 kg

VF60:

913 383 for 16 mm rebate: 390 kg
913 593 for 22 mm rebate: 350 kg
913 342 for 32 mm rebate: 320 kg
913 343 for 42 mm rebate: 310 kg

8. Calculation example

Given:	Mullion axis distance:	1.2 m
	Mullion fixing distance:	3.2 m
	Transom axis distance:	2.4 m
	Filling weight (Pyrostop-type 30-17) : 57 kg/m² >	164 kg
	Installation height <= 18 m	

Sought after: Mullion profile according to static requirements
Transom profile according to static requirements

Mullion selection:

Worst assumption: wind pressure peripheral range > table 4
Mullion distance 1.2 m, height 3.2 m.
Possible mullions: 519354 / 519355 / 519356 / 519104 / 519105 / 523103 / 523104 / 523105

Transom selection:

Horizontal occurrence of powers:
Load type assumption 2^{nd}, transom distance 2.4 m > table 9.
Possible transoms: 519353 / 519354 / 519355 / 519356 / 519303 / 523303

Vertical occurrence of powers:
From diagram: Iy/G = 27 cm^4/kN
$I_{y,erf.} = 27\ cm^4/kN \times 1{,}64\ kN = 44{,}3\ cm^4$
Possible transoms from profile overview: 519354 / 519355 / 519356 / 523302 / 523303

T-joint:

Complete evidence of the t-joints has been provided up to 195 kg.

Glass retainer:

Every glass retainer combination is able to cope with the filling weight of 164 kg.

Result:

Possible mullions: 519354 / 519355 / 519356 / 523103 / 523104 / 523105
Possible transoms: 519354 / 519355 / 519356 / 523303

9 Building physics

9.1 Determination of U_{cw}-value

Determination of the U_{cw}-value of a curtain wall façade is done in accordance with prEN 13 947. U_{cw} is defined as

$$U_{CW} = \frac{A_g U_g + A_f U_f + l_g \Psi_g + A_p U_p + l_p \Psi_p}{A_g + A_f + A_p}$$

The Ψ_p-values for cranked panels (thickness of panel edges comparable to thickness of insulating glass) depend on the thermal conductivity of the spacers used and are tabled in accordance with prEN 13 947:

Panel type	λ_{spacer} W/mK	Ψ_p W/mK
Aluminium / insulation / aluminium	0.2	0.16
	0.4	0.25
Glass / insulation / aluminium	0.2	0.14
	0.4	0.20
Glass / insulation / steel	0.2	0.13
	0.4	0.16

Note: prEN 13 947 does not provide Ψ –value for the interaction between interlocking fixed frames and façade profiles. In the version that is under revision at present a linear thermal transmittance $\Psi > 0$ is introduced.

9.2 U_f-values of façade profiles

The curves for the U_f-value were determined by the Institut für Fenstertechnik, Rosenheim by means of measurements in accordance with EN 12 412 – 2 and calculations in accordance with EN ISO 10 077 – 2. For each system there are U_f-value curves in dependence of the room-side profile depth l_f and the depth and the material of the insulating body between the room-side profile and the pressure plate profile. The curves apply for a thickness of 4 mm of the inside glazing profile.

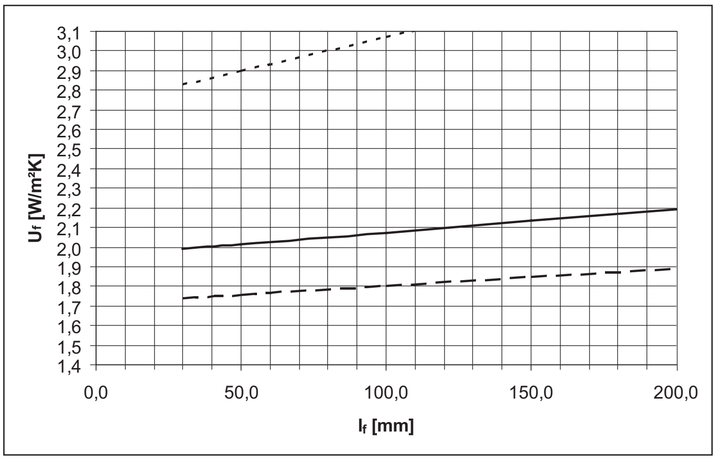
Test reports 432 25026/1 (PP spacer) apply to series BSC VF 50 / BSC VF50RR.

Test reports 432 26574/1 (PP spacer) apply to series BSC VF 60.

The curves can be transferred to comparable profile sections if the sections conform to the system design in their insulating principle (shell clearance, size and shape of the glazing gaskets).

The coating of the profiles has no influence on the U_f-value.

9.2.1 Series BSC VF 50 — Transom profiles with PP spacers
Series BSC VF 50 RR — Profiles with PP spacers



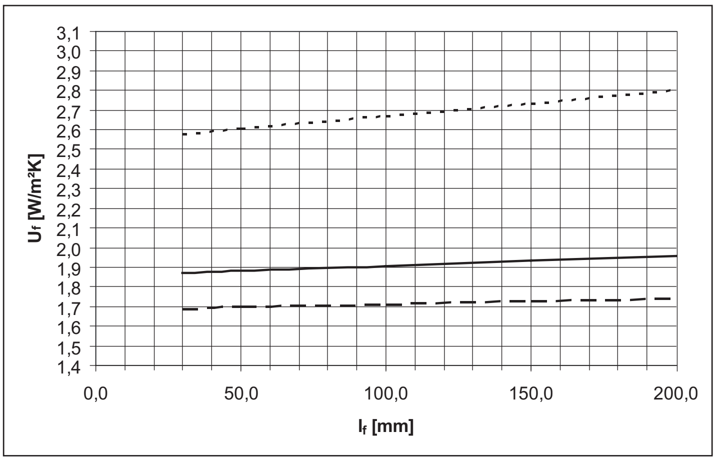
U_f -values in accordance with test certificate 432 25026/1

Spacer 910 064 (– – – – – – – – –)
(Glass thickness 4 – 12 mm)
U_f [W/m²K] = 0.0034 * l_f + 2.7298

Spacer 910 066 (————)
(Glass thickness 20 – 28 mm)
U_f [W/m²K] = 0.0012 * l_f + 1.9537

Spacer 910 068 (– – – – – – – – –)
(Glass thickness 30 – 38 mm)
U_f [W/m²K] = 0.0009 * l_f + 1.7104

9.2.2 Series BSC VF 50 — Mullion profiles with PP spacers



U_f -values in accordance with test certificate 432 25026/1

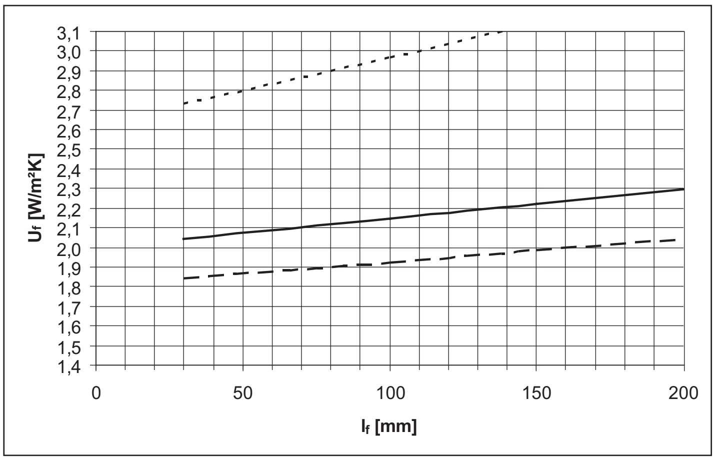
Spacer 910 065 (– – – – – – – – –)
(Glass thickness 4 – 12 mm)
U_f [W/m²K] = 0.0013 * l_f + 2.5400

Spacer 910 067 (————)
(Glass thickness 20 – 28 mm)
U_f [W/m²K] = 0.0005 * l_f + 1.8577

Spacer 910 069 (– – – – – – – – –)
(Glass thickness 30 – 38 mm)
U_f [W/m²K] = 0.0003 * l_f + 1.6808

9.2.3 Series VF 60 Transoms with PP spacers

Pressure plate profile with continuous gasket (911 930)



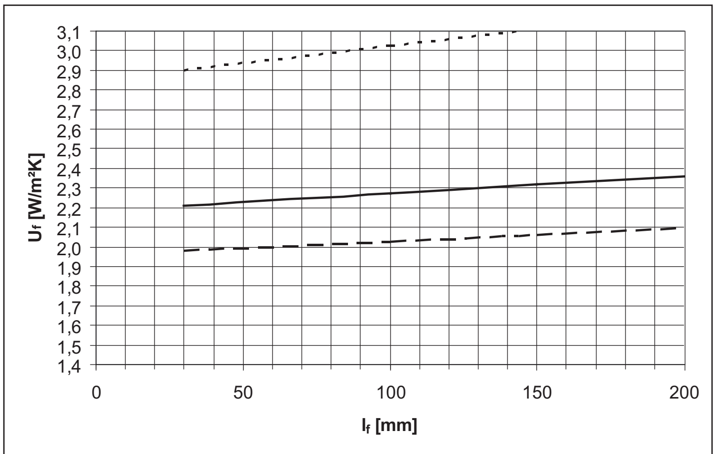
U_f -values in accordance with test certificate 432 26574/1

Spacer 910 065
(Glass thickness 4 – 12 mm)
U_f [W/m²K] = 0.0034 * l_f + 2.6284

Spacer 910 067
(Glass thickness 20 – 28 mm)
U_f [W/m²K] = 0.0015 * l_f + 1.9977

Spacer 910 069
(Glass thickness 30 – 38 mm)
U_f [W/m²K] = 0.0012 * l_f + 1.8054

9.2.4 Series VF 60 Mullions with PP spacers



U_f -values in accordance with test certificate 432 26574/1

Spacer 910 065
(Glass thickness 4 – 12 mm)
U_f [W/m²K] = 0.0018 * l_f + 2.8425

Spacer 910 067
(Glass thickness 20 – 28 mm)
U_f [W/m²K] = 0.0009 * l_f + 2.1814

Spacer 910 069
(Glass thickness 30 – 38 mm)
U_f [W/m²K] = 0.0007 * l_f + 1.9572