

GUIDANCE PAPER

VELUX MODULAR SKYLIGHTS

SELF-SUPPORTING RIDGELIGHT

Determination of structural design values

1. Introduction

The aim of this document – together with ETA 17/0467 of 2019-01-28 is to provide guidance to the determination of design values.

ETA-17/0467 contains information on the kit, e.g. the structural system, hardware, cross section of the profiles, as well as the characteristic values. For convenience, a number of the relevant characteristic values are repeated in this document.

By means of structural calculations and design values, it can be demonstrated whether the requirements of the load bearing capacity of a specific kit, installed in a given building on a given location, are met.

The calculations should be carried out by a competent body.

The examples in this document demonstrate how the calculations **could** be carried out. National Standards and Annexes may specify different loads and combinations hereof, that are not mentioned in this document.

The load bearing capacity of the glazing is not subject to this document.

2. Principle

The design load bearing capacities (1) R_d and C_d shall be calculated using the following equations (see ETAG 010, 6.3.1.1 and 6.3.1.2):

$$R_d = R_k / (\gamma_{MR} * K_t * K_u * K_\theta)$$

and

$$C_d = C_k / (\gamma_{MC} * C_t * C_u * C_\theta)$$

where:

R_k	=	Characteristic load bearing capacity (ULS) calculated in accordance with ETA-17/0467
C_k	=	Characteristic load bearing capacity (SLS) calculated in accordance with ETA-17/0467
γ_{MR}	=	partial safety factor for ULS
γ_{MC}	=	partial safety factor for SLS
K_t	=	effect of duration for ULS (2)
C_t	=	effect of duration for SLS (2)
K_u	=	effect of ageing/environment for ULS (2)



C_u	=	effect of ageing/environment for SLS (2)
K_θ	=	effect of temperature for ULS (2)
C_θ	=	effect of temperature for SLS (2)

Notes:

- (1) The self-weight, including partial safety factors, shall be calculated in accordance with Clause 6.
 (2) Relevant only for profiles and hardware connections connected to the profiles.

3. Partial safety factors, magnification and reduction factors

Whenever possible internationally and/or nationally determined parameters and factors shall be taken into account. By default, the parameters and factors shown in Table 1 and Table 2 and Table 5 are recommended.

The recommended parameters are based on:

“BÜV-Empfehlung Tragende Kunststoffbauteile im Bauwesen [TKB] - Entwurf, Bemessung und Konstruktion - Stand 08 / 2010” (BÜV) and some European standards and VELUX test reports.

Table 1: Partial safety factors

Partial safety factor	γ_{MR}	γ_{MC}
Frame profiles at connections	1,5 (1)	Not relevant
Bolt/Rivet/Bracket/Rotating shoe/Mounting clamp	1,25 (2)	Not relevant
Frame profiles	1,2 (1)	1,1 (3)

Notes:

- (1) See BÜV Tabelle E-1
 (2) See EN 1993-1-8:2005, section 2.2
 (3) See BÜV Abschnitt 5.5

Table 2: Magnification and reduction factors (8)

ULS			SLS		
K_t (1) (2)	10 minutes	1,10	C_t (1) (4)	10 minutes	1,02
	1 week	1,48		1 week	1,08
	3 weeks	1,55		3 weeks	1,09
	1 month	1,58		1 month	1,10
	3 months	1,66		3 months	1,11
	6 months	1,71		6 months	1,11
	25 years	2,02		25 years	1,15
K_u (1) (3)	1,2		C_u (1) (5)	1,2	
K_θ (1)	0°C (6)	0,95	C_θ (1)	0°C (6)	1,00
	20°C (6)	1,00		20°C (6)	1,00
	40°C (7)	1,35		40°C (7)	1,05
	60°C (6)	1,50		60°C (6)	1,05
	80°C (6)	2,05		80°C (6)	1,10

Notes:

- (1) $K_t = A_{1f}$, $C_t = A_{1E}$ (see ETAG 010: 2002, section 6.3 and Annex H, BÜV Abschnitt 5.2)
 $K_u = A_{2f}$, $C_u = A_{2E}$ (see ETAG 010: 2002, section 6.3 and Annex H, BÜV Abschnitt 5.2)
 $K_\theta = A_{3f}$, $C_\theta = A_{3E}$ (see ETAG 010: 2002, section 6.3 and Annex H, BÜV Abschnitt 5.2)
- (2) See BÜV Tabelle B-1a and Gleichung 8.2.
 (3) See BÜV Tabelle B-2.
 (4) See BÜV Tabelle B-1b and Gleichung 8.2.
 (5) See BÜV Tabelle B-2.
 (6) See VELUX test reports no. 147775 and 145611 and DTI report no. 743795-2.
 (7) Conservative approximation based on measurements from VELUX test reports nos. 147775 and 145611.
 (8) Relevant only for profiles and their hardware connections.

4. Design values of small scale tests

The design values of the small-scale tests can be calculated as shown in Table 3.

Table 3: Characteristic and design values

Property	Characteristic values see ETA-17/0467 Annex D.1	Design values see Table 1 and Table 2 above
Tensile strength	832,9 MPa	ULS= Characteristic value / $(\gamma_{MR} * K_t * K_u * K_\theta)$ SLS= Characteristic value / $(\gamma_{MC} * C_t * C_u * C_\theta)$
Compression strength	465 MPa	
Bending strength	1257 MPa	
E-modulus	39,5 GPa	
	41,6 GPa (1)(3)	
G-modulus	3,1 GPa	
	3,4 GPa (2)	
Shear strength	53,8 MPa	

Notes:

- (1) Mean value, confidence level 75%, unknown standard deviation (See ISO 16269-6:2014).
 (2) Mean value, confidence level 75%, unknown standard deviation (See ISO 16269-6:2014).
 (3) For openable windows subjected to a downward action force, the E-modulus shall be multiplied with a factor of 0,83, see "VELUX report 1100005818_06_1 VMS Full scale test Ridgelight – Stiffness of module 2016-11-29"



5. Determination of values for hardware connections

Figure 1: Applied forces to the hardware

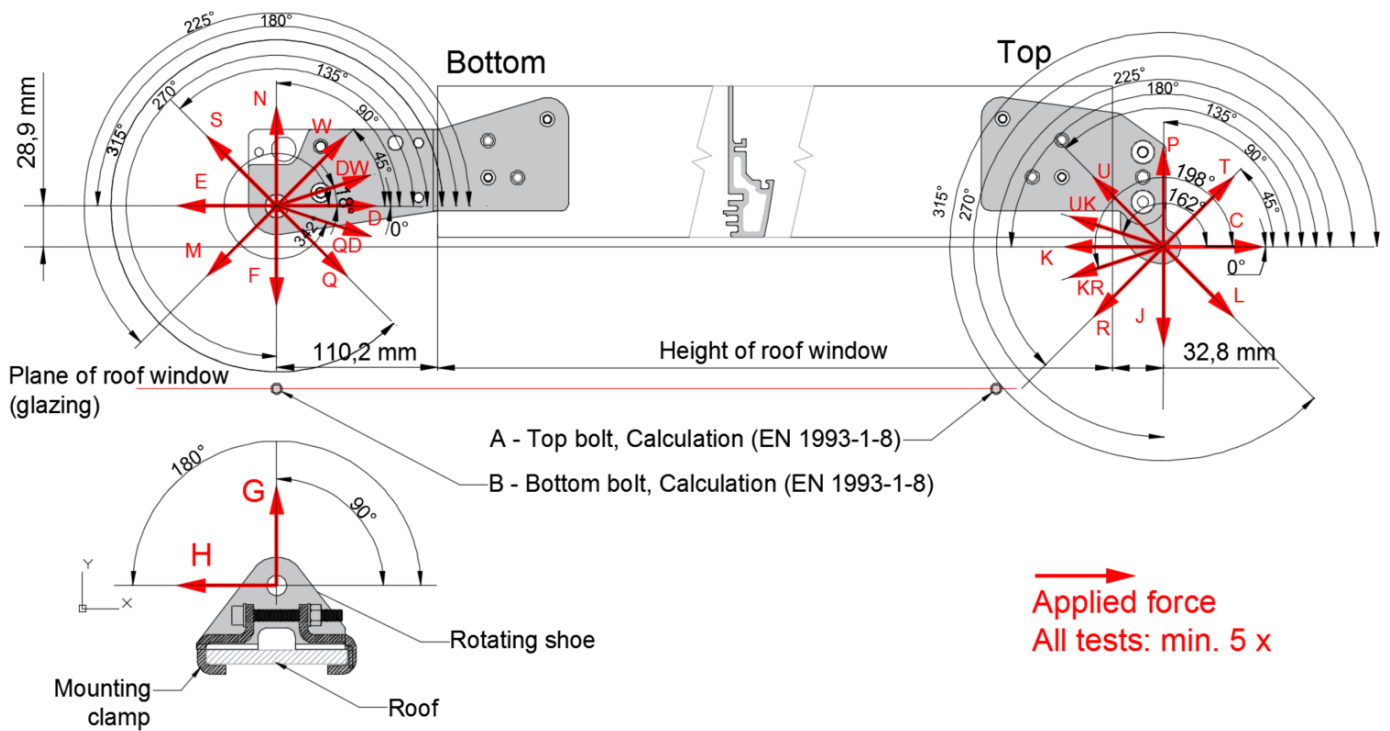


Table 4: Characteristic and design values for hardware connections

	Element/Connection	Characteristic value R _k [kN]	Design value R _d [kN] see Table 1
A	Top bolt connection (calculated minimum)	13,5 (1)	ULS= Characteristic value / γ _{MR}
B	Bottom bolt connection (calculated minimum)	17,6 (1)	
G	Rotating shoe/mounting clamp/roof connection in 90°	20,3	
H	Rotating shoe/mounting clamp/roof connection in 180°	28,2	SLS: Not relevant

Note:

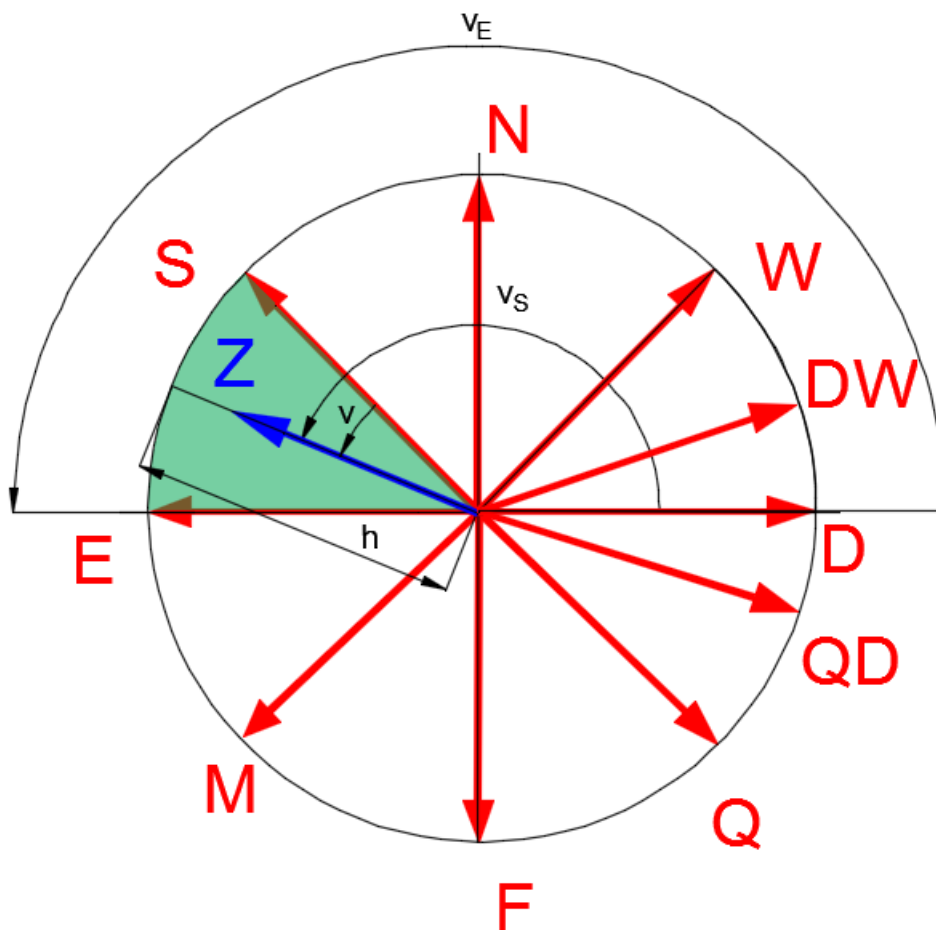
(1) Strength of the bottom and top bolt themselves: 17,6 kN

	Element/Connection	Characteristic Value R _k [kN] (1)			
		Product variant			
		HFC 100240 0010B	HVC 100240 0010B	HFC 100240 0016TB	HVC 100240 0016TB
C	Top corner bracket/frame connection in 0°	8,5	11,2	9,0	10,9
D	Bottom corner bracket/frame connection in 0°	11,9	11,9	10,9	12,4
E	Bottom corner bracket/frame connection in 180°	8,5	11,2	9,0	10,9
F	Bottom corner bracket/frame connection in 270°	3,9	2,0	4,3	2,1
J	Top corner bracket/frame connection in 270°	3,9	2,0	4,3	2,1
K	Top corner bracket/frame connection in 180°	11,9	11,9	10,9	12,4
L	Top corner bracket/frame connection in 315°	6,2	3,4	6,0	3,5
M	Bottom corner bracket/frame connection in 225°	6,2	3,4	6,0	3,5
N	Bottom corner bracket/frame connection in 90°	6,0	6,0	6,2	5,7
P	Top corner bracket/frame connection in 90°	6,0	6,0	6,2	5,7
Q	Bottom corner bracket/frame connection in 315°	5,4	3,0	5,0	3,6
R	Top corner bracket/frame connection in 225°	5,4	3,0	5,0	3,6
S	Bottom corner bracket/frame connection in 135°	7,8	8,2	8,1	7,5
T	Top corner bracket/frame connection in 45°	7,8	8,2	8,1	7,5
U	Top corner bracket/frame connection in 135°	8,6	9,3	8,6	9,0
W	Bottom corner bracket/frame connection in 45°	8,6	9,3	8,6	9,0
DW	Bottom corner bracket/frame connection in 18°	13,8	16,8	13,3	17,1
UK	Top corner bracket/frame connection in 162°	13,8	16,8	13,3	17,1
QD	Bottom corner bracket/frame connection in 342°	10,0	6,4	10,2	6,1
KR	Top corner bracket/frame connection in 198°	10,0	6,4	10,2	6,1

Note:

(1) Without influence caused by nationally determined magnification and reduction factors (duration, aging/environment, temperature, i.e. C_t = C_u = C₀ = 1 and K_t = K_u = K₀ = 1, see ETAG 010, 6.3.1.2)

Figure 2: Determination of values for hardware connections in other directions than tested (principle)



Z: Result of structural calculations [kN]

v : Result of structural calculations [degrees]

h: Result of a linear interpolation [kN]

$$h = S + v^{\circ} * (E - S) / (v_E^{\circ} - v_S^{\circ})$$

Requirement: $h \geq Z$



6. Self-weight

The self-weight (including hardware, lining, cladding and flashing) of the fixed roof window (G_f and g_f) and the openable roof window (G_v and g_v) shall be calculated as follows:

$$G_f = (W-12) * (L-96) * t * 25 * 10^{-9} + 2(W+L) * 57 * 10^{-6} \quad [\text{kN}]$$

$$g_f = G_f / (W * L) * 10^6 \quad [\text{kN/m}^2]$$

and

$$G_v = (W-12) * (L-96) * t * 25 * 10^{-9} + 2(W+L) * 96 * 10^{-6} \quad [\text{kN}]$$

$$g_v = G_v / (W * L) * 10^6 \quad [\text{kN/m}^2]$$

where:

W = Width of the roof window in mm
L = Height of the roof window in mm
t = Sum of glass thicknesses in mm

Table 5: Partial safety factors for permanent action (self-weight):

	Unfavourable $\gamma_{G,sup}$	Favourable $\gamma_{G,inf}$	Unfavourable $\xi_{G,sup}$	Reference
ULS	1,35	1,0	0,85	EN 1990:2007, Table A1.2(B), Eq. 6.10b
SLS	1,0	1,0	N/A	EN 1990:2007, Table A1.4

7. Load combinations

According to BÜV Abschnitt 8.2 the load combinations can be divided up into 3 load durations.

1. Long term, only self-weight
2. Medium term, self-weight and snow load
3. Short term, self-weight, snow load and wind load

In medium term, only the snow load is set as dominate load regarding the load combinations from EN 1990:2007

In short term respectively snow and wind load is set as the dominate load.

8. Load bearing capacity for wind suction

For an openable window subjected to a perpendicular upward force the connection between the casement and frame profile is to be investigated.

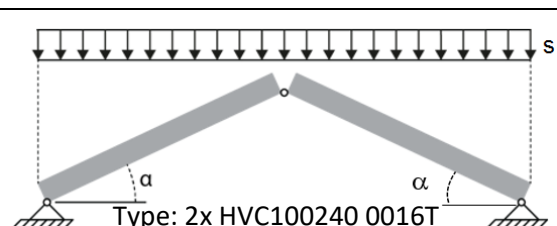
The load bearing capacity is found in VELUX report: "11000008316_30_0 VMW Suction on venting Frames" dated 2017-12-08 and shown in Table 6.

Table 6: Characteristic load bearing capacity for openable windows between casement and frame profile, for a suction force perpendicular to the window frame

	Load bearing capacity
Double glazing	8,87 kN
Triple glazing	8,72 kN

9. Examples of design values for the load bearing capacity

Table 7a: Characteristic and design load bearing capacities for snow-load

					Design calculation Self-weight partial safety factors (see Table 5): $\gamma_{G,sup,ULS}=1,35$ $\xi_{G,sup,ULS}=0,85$ $\gamma_{G,sup,SLS}=1,00$ Material partial safety factors (see Table 1): $\gamma_{MR,ULS}=1,50$ $\gamma_{MC,SLS}=1,10$ Magnification and reduction factors (see Table 2): Medium term - snow load (1): 3 months duration, 20°C. $K_t=1,66$; $K_u=1,2$; $K_\theta=1,00$ $C_t=1,11$; $C_u=1,2$; $C_\theta=1,00$ Load factor snow, from EN 1990:2007: $\gamma_{Q,1} = 1,5$ E- modulus: $E= 0,83 \times 41,6 \text{ GPa}$ See Note 3 to Table 3.		
	Characteristic values for s see ETA-17/0467 Annex E.1						
Application examples – Snow-load	α°	ULS [kN/m ²]	SLS [kN/m ²]		ULS (2) [kN/m ²]	SLS (3) [kN/m ²]	
			1/300	1/150		1/300	1/150
 Type: 2x HVC100240 0016T (1000mm x 2400mm) Glazing: 22 mm glass in total	25°	9,0	1,5	3,8	2,33	0,53	1,81
	30°	10,6	1,6	4,0	2,84	0,59	1,93
	35°	12,0	1,7	4,2	3,31	0,67	2,08
	40°	13,7	1,9	4,6	3,81	0,76	2,27

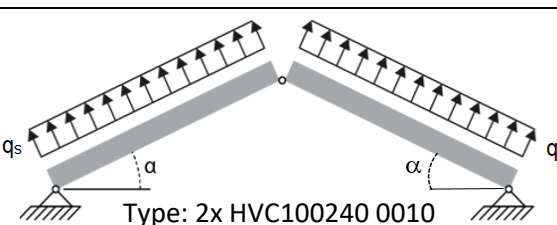
Notes:

(1) Load combination ULS: $\gamma_{G,sup} \cdot \xi_{G,sup} \cdot G_k + \gamma_{Q,1} \cdot s_k$ SLS: $G_k + s_k$

(2) Values in Table are design snow load for ULS: $\gamma_{Q,1} \cdot s_k$

(3) Values in Table are design snow load for SLS: s_k

Table 7b: Characteristic and design load bearing capacities for wind suction

					Design values Self-weight partial safety factors (see Table 5): $\gamma_{G,inf,ULS}=1,00$ $\gamma_{G,sup,SLS}=1,00$ Material partial safety factors (see Table 1): $\gamma_{MR,ULS}=1,50$ $\gamma_{MC,SLS}=1,10$ Magnification and reduction factors (see Table 2): Short term - wind load (2): 10 minutes, 60°C (1). ULS: $K_t=1,10$; $K_u=1,2$; $K_\theta=1,50$ SLS: $C_t=1,02$; $C_u=1,2$; $C_\theta=1,05$ Load factor wind, from EN 1990:2007: $\gamma_{Q,1} = 1,5$		
Application examples – Wind suction	α°	ULS [kN/m ²]	SLS [kN/m ²]		ULS (3) [kN/m ²]	SLS (4) [kN/m ²]	
			1/300	1/150		1/300	1/150
 <p>Type: 2x HVC100240 0010 (1000mm x 2400mm) Glazing: 14 mm glass in total</p>	25°	5,0	1,9	3,4	2,01 (5)	1,53	2,53
	30°	5,1	1,9	3,3	2,05 (5)	1,51	2,51
	35°	5,0	1,9	3,3	1,77 (5)	1,48	2,48
	40°	4,4	1,9	3,3	1,79 (5)	1,45	2,45

Notes:

- (1) See VELUX test report 149292.
- (2) Load combination ULS: $\gamma_{G,inf} \cdot G_k + \gamma_{Q,1} \cdot q_{s,k}$ SLS: $G_k + q_{s,k}$
- (3) Values in Table are design snow load for ULS: $\gamma_{Q,1} \cdot q_{s,k}$
- (4) Values in Table are design snow load for SLS: $q_{s,k}$
- (5) Failure between casement and frame profile, see Clause 8

10. Calculation example, asymmetric load (design values)

For the calculations example "Asymmetric load" the same example as Annex E.2 in ETA-17/0467 is used.

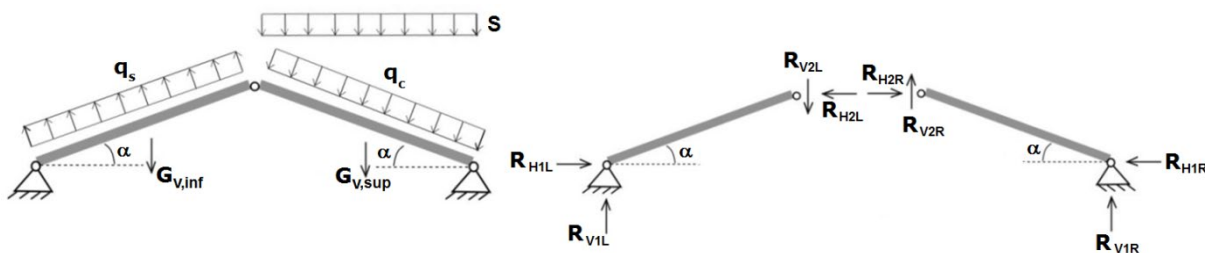
To demonstrate the calculation procedure, a VELUX modular skylight self-supporting ridgetlight application under asymmetric wind and snow load is examined.

Geometry and roof window variant is the same as in the wind load example in Table 7b:

2 x HVC1002400 0010 (1000mm x 2400mm). Glazing: 14mm glass in total.

The pitch is $\alpha = 25^\circ$.

Figure 3: Load model for calculation example



Partial safety factors and the magnification and reduction factors used in the calculation are presented in Tables 8a and 8b.

Table 8a: Partial safety factors

	ULS	SLS
Frame profiles at connections:	$\gamma_{MR} = 1,5$	N/A
Frame profiles:	$\gamma_{MR} = 1,2$	$\gamma_{MC} = 1,1$
Variable Load, leading:	$\gamma_{Q,1} = 1,5$ (1)	$\gamma_{Q,1} = 1,0$ (1)
Variable Load, non-leading:	$\gamma_{Q,i} = 1,5$ (1)	$\gamma_{Q,i} = 1,0$ (1)
Permanent action, unfavourable:	$\gamma_{G,sup} = 1,35$	$\gamma_{G,sup} = 1,0$
Permanent action, favourable:	$\gamma_{G,inf} = 1,0$	$\gamma_{G,inf} = 1,0$
Factor for combination, wind	$\Psi_{0,wind} = 0,6$ (1)	$\Psi_{0,wind} = 0,6$ (1)
Factor for combination, snow	$\Psi_{0,snow} = 0,5$ (1)	$\Psi_{0,snow} = 0,5$ (1)
Reduction factor for G_{sup}	$\xi_{G,sup} = 0,85$	N/A

Note:

(1) See EN 1990:2007

Table 8b: Magnification and reduction factors

	ULS	SLS
Duration dependency, self-weight leading:	$K_{t,25\text{ years}} = 2,02$	$C_{t,25\text{ years}} = 1,15$
Duration dependency, wind leading:	$K_{t,10\text{ min}} = 1,1$	$C_{t,10\text{ min}} = 1,02$
Duration dependency, snow leading:	$K_{t,3\text{ month}} = 1,66$	$C_{t,3\text{ month}} = 1,11$
Ageing/environment dependency:	$K_u = 1,2$	$C_u = 1,2$
Temperature dependency, 20°C:	$K_{\theta,20^\circ} = 1,0$	$C_{\theta,20^\circ} = 1,00$
Temperature dependency, 60°C:	$K_{\theta,60^\circ} = 1,5$	$C_{\theta,60^\circ} = 1,05$

Table 9: Brackets characteristic load bearing capacity

Element/Connection	Characteristic values R_k [kN]
A: Top bolt connection (calculated minimum)	13,5 (1)
B: Bottom rivet connection (calculated minimum)	17,6
C: Top corner bracket/frame connection in 0°	11,2
D: Bottom corner bracket/frame connection in 0°	11,9
E: Bottom corner bracket/frame connection in 180°	11,2
F: Bottom corner bracket/frame connection in 270°	2,0
G: Rotating shoe/mounting clamp/roof connection in 90°	20,3
H: Rotating shoe/mounting clamp/roof connection in 180°	28,2
J: Top corner bracket/frame connection in 270°	2,0
K: Top corner bracket/frame connection in 180°	11,9
L: Top corner bracket/frame connection in 315°	3,4
M: Bottom corner bracket/frame connection in 225°	3,4
N: Bottom corner bracket/frame connection in 90°	6,0
P: Top corner bracket/frame connection in 90°	6,0
Q: Bottom corner bracket/frame connection in 315°	3,0
R: Top corner bracket/frame connection in 225°	3,0
S: Bottom corner bracket/frame connection in 135°	8,2
T: Top corner bracket/frame connection in 45°	8,2
U: Top corner bracket/frame connection in 135°	9,3
W: Bottom corner bracket/frame connection in 45°	9,3
DW: Bottom corner bracket/frame connection in 18°	16,8
UK: Top corner bracket/frame connection in 162°	16,8
QD: Bottom corner bracket/frame connection in 342°	6,4
KR: Top corner bracket/frame connection in 198°	6,4

Note:

(1) Strength of the bolt itself: 17,6 kN

Corrections in height and angle

Because of the brackets, it is necessary to correct the calculation angle and the profile height. In Figure 1 $\Delta L_1 = 110,2$ mm and $\Delta L_2 = 43,7$ mm for the brackets can be found. ΔL_2 can be transformed into a parallel part $\Delta L_{2||} = 32,8$ mm and a perpendicular part $\Delta L_{2\perp} = 28,9$ mm.

ΔL_1 and ΔL_2 are constants no matter the height L or angle α of the glazing.

The corrected height can thereby be found:

$$L_{cor} = \sqrt{(L + \Delta L_1 + \Delta L_{2ll})^2 + (L_{2\perp})^2} = \sqrt{(2400mm + 110,2mm + 32,8mm)^2 + (28,9mm)^2} = 2543mm$$

The corrected angle is found:

$$\Delta\alpha = \sin^{-1}\left(\frac{\Delta L_{2\perp}}{L + \Delta L_1 + \Delta L_{2ll}}\right) = \sin^{-1}\left(\frac{28,9mm}{2400mm + 110,2mm + 32,8mm}\right) = 0,65^\circ$$

$$\alpha_{cor} = \alpha - \Delta\alpha = 25^\circ - 0,7^\circ = 24,3^\circ$$

For deflection calculations of an upwards load for an openable window, only the casement will deflect. Therefore only the height of the casement profile and correct angle hereof should be used for the deflections calculations. From Figure 4 $\Delta L_{1,up,dfl} = -9,7$ mm, $\Delta L_{2ll,up,dfl} = 23,5$ mm and $\Delta L_{2\perp,up,dfl} = 24$ mm are found.

The corrected height $L_{cor,up,dfl}$ can thereby be found:

$$L_{cor,up,dfl} = \sqrt{(L + \Delta L_{1,up,dfl} + \Delta L_{2ll,up,dfl})^2 + (L_{2\perp,up,dfl})^2}$$

$$= \sqrt{(2400mm - 9,7mm + 23,5mm)^2 + (24mm)^2} = 2414mm$$

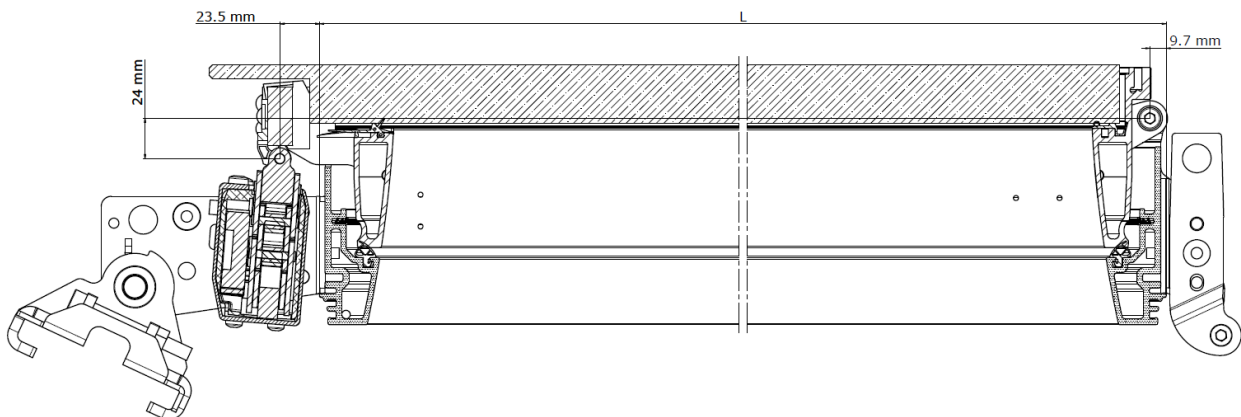
The corrected angle is found:

$$\Delta\alpha_{up,dfl} = \sin^{-1}\left(\frac{L_{2\perp,up,dfl}}{L + \Delta L_{1,up,dfl} + \Delta L_{2ll,up,dfl}}\right)$$

$$= \sin^{-1}\left(\frac{24mm}{2400mm - 9,7mm + 23,5mm}\right) = 0,57^\circ$$

$$\alpha_{cor,up,dfl} = \alpha + \Delta\alpha_{up,dfl} = 25^\circ + 0,6^\circ = 25,6^\circ$$

Figure 4: Corrections vectors for an openable window subjected to an upwards acting force, deflections only



The measurements $\Delta L_{1,up,dfl} = -9,7$ mm, $\Delta L_{2ll,up,dfl} = 23,5$ mm and $\Delta L_{2\perp,up,dfl} = 24$ mm are constants.

Characteristic loads

Self-weight on each side frame/casement:

$$G_{V,k} = \frac{1}{2} \cdot ((W - 12) \cdot (L - 96) \cdot t \cdot 25 \cdot 10^{-9} + 2 \cdot (W + L) \cdot 96 \cdot 10^{-6})$$

$$= \frac{1}{2} \cdot ((1000 - 12) \cdot (2400 - 96) \cdot 14 \cdot 25 \cdot 10^{-9} + 2 \cdot (1000 + 2400) \cdot 96 \cdot 10^{-6}) = 0,72kN$$

To be able to divide the self-weight up in sup and inf, the self-weight is given for the left and the right

frame/casement.

$$G_{VL,k} = G_{VR,k} = 0,72kN$$

In this example, the wind peak velocity pressure ($q_{p,k}$) is set to $0,8kN/m^2$ and the shape factor (c) is set to $0,5$ for wind pressure and $-0,5$ for wind suction. Hence, the load is

$$q_{c,k} = q_{s,k} = q_{p,k} \cdot c \cdot W/2 = 0,8kN/m^2 \cdot 0,5 \cdot 1,0m/2 = 0,2kN/m, \text{ on each side frame/casement}$$

The wind load is split into a vertical and a horizontal component, using the original angle α . Using the corrected height, L_{cor} to find the equivalent concentrated load.

$$Q_{SH,k} = Q_{CH,k} = q_{c,k} \cdot L_{cor} \cdot \sin(\alpha) = 0,2kN/m \cdot 2,543m \cdot \sin(25^\circ) = 0,21kN \text{ on each side frame/casement}$$

$$Q_{SV,k} = Q_{CV,k} = q_{c,k} \cdot L_{cor} \cdot \cos(\alpha) = 0,2kN/m \cdot 2,543m \cdot \cos(25^\circ) = 0,46kN \text{ on each side frame/casement}$$

For the snow load in this example the two C factors (according to EN 1991-1-3) are set to $1,0$, the shape factor μ_2 set to $0,8$ and the characteristic value of snow load on the ground $S_k=1,0kN/m^2$, given the characteristic snow load s_k :

$$s_k = \mu_2 \cdot C_e \cdot C_t \cdot S_k = 0,8 \cdot 1,0 \cdot 1,0 \cdot 1,0kN/m^2 = 0,8kN/m^2 \rightarrow s_{s,k} = 0,4kN/m, \text{ on each side frame/casement}$$

The snow load is only vertical, and the corrected height L_{cor} is used to find the equivalent concentrated load.

$$S_{V,k} = s \cdot \cos(\alpha) \cdot L_{cor} = 0,4kN/m \cdot \cos(25^\circ) \cdot 2,543m = 0,92kN$$

Reactions in brackets

The corrected height L_{cor} and angle α_{cor} are used in the static system to determine the reactions.

These calculations are not presented here.

Reactions are calculated separately for each load type and are found in Table 10.

From the characteristic reactions, different load combinations are made from the partial safety factors found in Table 8a. CC2 (see EN 1990:2007, Table B1) is assumed:

a) Characteristic load combination:

$$1,0 \cdot G_{VL,k} + 1,0 \cdot G_{VR,k} + 1,0 \cdot Q_k + 1,0 \cdot S_{V,k}$$

b) Long term: Dominant self-weight combination:

$$\gamma_{G,sub} \cdot G_{VL,k} + \gamma_{G,sup} \cdot G_{VR,k} \Rightarrow$$

$$1,35 \cdot G_{VL,k} + 1,35 \cdot G_{VR,k}$$

c) Medium term: Dominant snow combination:

$$\gamma_{G,inf} \cdot G_{VL,k} + \gamma_{G,sup} \cdot \xi_{G,sup} \cdot G_{VR,k} + \gamma_{Q,1} \cdot S_{V,k} \Rightarrow$$

$$1,0 \cdot G_{VL,k} + 1,35 \cdot 0,85 \cdot G_{VR,k} + 1,5 \cdot S_{V,k}$$

d) Short term: Dominant wind combination, with snow:

$$\gamma_{G,inf} \cdot G_{VL,k} + \gamma_{G,sup} \cdot \xi_{G,sup} \cdot G_{VR,k} + \gamma_{Q,1} \cdot Q_k + \gamma_{Q,i} \cdot \Psi_{0,snow} \cdot S_{V,k} \Rightarrow$$

$$1,0 \cdot G_{VL,k} + 1,35 \cdot 0,85 \cdot G_{VR,k} + 1,5 \cdot Q_k + 1,5 \cdot 0,5 \cdot S_{V,k}$$

e) Short term: Dominant wind combination, without snow:

$$\gamma_{G,inf} \cdot G_{VL,k} + \gamma_{G,sup} \cdot \xi_{G,sup} \cdot G_{VR,k} + \gamma_{Q,1} \cdot Q_k \Rightarrow$$

$$1,0 \cdot G_{VL,k} + 1,35 \cdot 0,85 \cdot G_{VR,k} + 1,5 \cdot Q_k$$

f) Short term: Dominant snow combination, with wind:

$$\gamma_{G,inf} \cdot G_{VL,k} + \gamma_{G,sup} \cdot \xi_{G,sup} \cdot G_{VR,k} + \gamma_{Q,i} \cdot \Psi_{0,wind} \cdot Q_k + \gamma_{Q,1} \cdot S_{V,k} \Rightarrow$$

$$1,0 \cdot G_{VL,k} + 1,35 \cdot 0,85 \cdot G_{VR,k} + 1,5 \cdot 0,6 \cdot Q_k + 1,5 \cdot S_{V,k}$$

Table 10, Horizontal and vertical reactions of the brackets

Load type	R _{H1L} [kN]	R _{V1L} [kN]	R _{H2L} [kN]	R _{V2L} [kN]	R _{H2R} [kN]	R _{V2R} [kN]	R _{H1R} [kN]	R _{V1R} [kN]
G _{VL,k}	0,40	0,54	0,40	-0,18	0,40	-0,18	0,40	0,18
G _{VR,k}	0,40	0,18	0,40	0,18	0,40	0,18	0,40	0,54
Q _k (Q _{s,k} and Q _{c,k})	0,21	-0,18	0,00	0,28	0,00	0,28	-0,21	0,18
S _{V,k}	0,51	0,23	0,51	0,23	0,51	0,23	0,51	0,69
a) Characteristic combi.	1,52	0,77	1,31	0,51	1,31	0,51	1,10	1,59
b) Long term: Dom. self-weight	1,08	0,97	1,08	0,00	1,08	0,00	1,08	0,97
c) Medium term: Dom. snow	1,62	1,09	1,62	0,37	1,62	0,37	1,62	1,83
d) Short term: Dom. wind	1,55	0,65	1,24	0,62	1,24	0,62	0,92	1,59
e) Short term: Dom. wind, -snow	1,17	0,47	0,86	0,44	0,86	0,44	0,54	1,07
f) Short term: Dom. snow	1,81	0,93	1,62	0,62	1,62	0,62	1,43	2,00

The factors to find the design value of the load bearing capacity of the bracket are found from the formula given in Clause 2 and Table 8b. Duration is divided up in long term (25 years), medium term (3 month) and short term (10 min), and temperature is taken for the highest it can be, 20°C when snow and 60°C when without snow. Hence self-weight is set to the lifespan of the window, snow duration is set to 3 months and wind duration set to 10 minutes. Snow duration may differ from region to region and should be changes accordingly.

Long term: Dominant self-weight combination, duration: 25 years, temperature: 60°C

$$b) \text{ factor} = \gamma_{MR} \cdot K_{t,25years} \cdot K_u \cdot K_{\theta,60^\circ} = 1,5 \cdot 2,02 \cdot 1,2 \cdot 1,5 = 5,45$$

Medium term: Dominant snow combination, duration: 3 months, temperature: 20°C:

$$c) \text{ factor} = \gamma_{MR} \cdot K_{t,3months} \cdot K_u \cdot K_{\theta,20^\circ} = 1,5 \cdot 1,66 \cdot 1,2 \cdot 1,0 = 2,99$$

Short term: Dominant wind combination, duration: 10 minutes, temperature: 20°C:

$$d) \text{ factor} = \gamma_{MR} \cdot K_{t,10min} \cdot K_u \cdot K_{\theta,20^\circ} = 1,5 \cdot 1,1 \cdot 1,2 \cdot 1,0 = 1,98$$

Short term: Dominant wind combination, no snow load, duration: 10 minutes, temperature: 60°C:

$$e) \text{ factor} = \gamma_{MR} \cdot K_{t,10min} \cdot K_u \cdot K_{\theta,60^\circ} = 1,5 \cdot 1,1 \cdot 1,2 \cdot 1,5 = 2,97$$

Short term: Dominant snow combination, duration: 10 minutes, temperature: 20°C:

$$f) \text{ factor} = \gamma_{MR} \cdot K_{t,10min} \cdot K_u \cdot K_{\theta,20^\circ} = 1,5 \cdot 1,1 \cdot 1,2 \cdot 1,0 = 1,98$$

The resulting bracket forces and utilization hereof are found in Table 11a to 11f for the load combinations. The load bearing capacities of the brackets in the resulting angle are found by linear interpolation between the two-neighbouring load bearing capacities, see Figure 2 and Table 9.

Table 11a, Brackets forces (resultants) and utilization for the characteristic load combination

a) Characteristic combi.	R _{1L}	R _{2L}	R _{2R}	R _{1R}
Characteristic bracket reaction force	1,70 kN	1,40 kN	1,40 kN	1,93 kN
Angle according to Figure 1	1,8°	176,2°	133,8°	30,4°
Characteristic load bearing capacity	12,40 kN	12,93 kN	9,21 kN	13,34 kN
Utilization	14 %	11 %	15 %	14 %



Table 11b, Brackets forces (resultants) and utilization for the long term dominant self-weight load combination

b) Long term: Dom. self-weight	R _{1L}	R _{2L}	R _{2R}	R _{1R}
Design bracket reaction force	1,45 kN	1,08 kN	1,08 kN	1,45 kN
Angle according to Figure 1	17,1°	155,0°	155,0°	17,1°
Characteristic load bearing capacity	16,55 kN	14,86 kN	14,86 kN	16,55 kN
Design load bearing capacity	3,04	2,73	2,73	3,04
Utilization	48 %	39 %	39 %	48 %

Table 11c, Brackets forces (resultants) and utilization for the medium term dominant snow load combination

c) Medium term: Dom. snow	R _{1L}	R _{2L}	R _{2R}	R _{1R}
Design bracket reaction force	1,95 kN	1,66 kN	1,66 kN	2,45 kN
Angle according to Figure 1	9,0°	167,9°	142,1°	23,6°
Characteristic load bearing capacity	14,34 kN	15,19 kN	11,27 kN	15,26 kN
Design load bearing capacity	4,80 kN	5,08 kN	3,77 kN	5,10 kN
Utilization	41 %	33 %	44 %	48 %

Table 11d, Brackets forces (resultants) and utilization for the short term dominant wind load combination

d) Short term: Dom. wind	R _{1L}	R _{2L}	R _{2R}	R _{1R}
Design bracket reaction force	1,68 kN	1,38 kN	1,38 kN	1,84 kN
Angle according to Figure 1	357,6°	181,4°	128,6°	34,9°
Characteristic load bearing capacity	11,15 kN	11,47 kN	8,83 kN	12,11 kN
Design load bearing capacity	5,63 kN	5,79 kN	4,46 kN	6,12 kN
Utilization	30 %	24 %	31 %	30 %

Table 11e, Brackets forces (resultants) and utilization for the short term dominant wind, without snow load combination

e) Short term: Dom. wind, -snow	R _{1L}	R _{2L}	R _{2R}	R _{1R}
Design bracket reaction force	1,26 kN	0,96 kN	0,96 kN	1,20 kN
Angle according to Figure 1	357,0°	182,3°	127,7°	38,3°
Characteristic load bearing capacity	10,98 kN	11,18 kN	8,76 kN	11,17 kN
Design load bearing capacity	3,70 kN	3,77 kN	2,95 kN	3,76 kN
Utilization	34 %	26 %	33 %	32 %

Table 11f, Brackets forces (resultants) and utilization for the short term dominant snow load combination

f) Short term: Dom. snow	R _{1L}	R _{2L}	R _{2R}	R _{1R}
Design bracket reaction force	2,03 kN	1,74 kN	1,74 kN	2,46 kN
Angle according to Figure 1	2,1°	176,0°	134,0°	29,4°
Characteristic load bearing capacity	12,48 kN	12,99 kN	9,23 kN	13,63 kN
Design load bearing capacity	6,30 kN	6,56 kN	4,66 kN	6,89 kN
Utilization	32 %	26 %	37 %	36 %

Load bearing capacity for wind suction

Since it is an openable window and the left side is subjected to wind suction, the load bearing capacity hereof is checked.

Dimension of the glass is found in Figure 5. The 60 mm protruded part is toughened glass with a thickness of 8 mm. The glass self-weight can hereby be found with a glass density of $\gamma_{\text{glass}} = 25 \text{ kN/m}^3$.

$$G_{\text{glass},k} = ((L - 0,056m) \cdot t + 0,060m \cdot 0,008m) \cdot (W - 0,022m) \cdot \gamma_{\text{glass}}$$

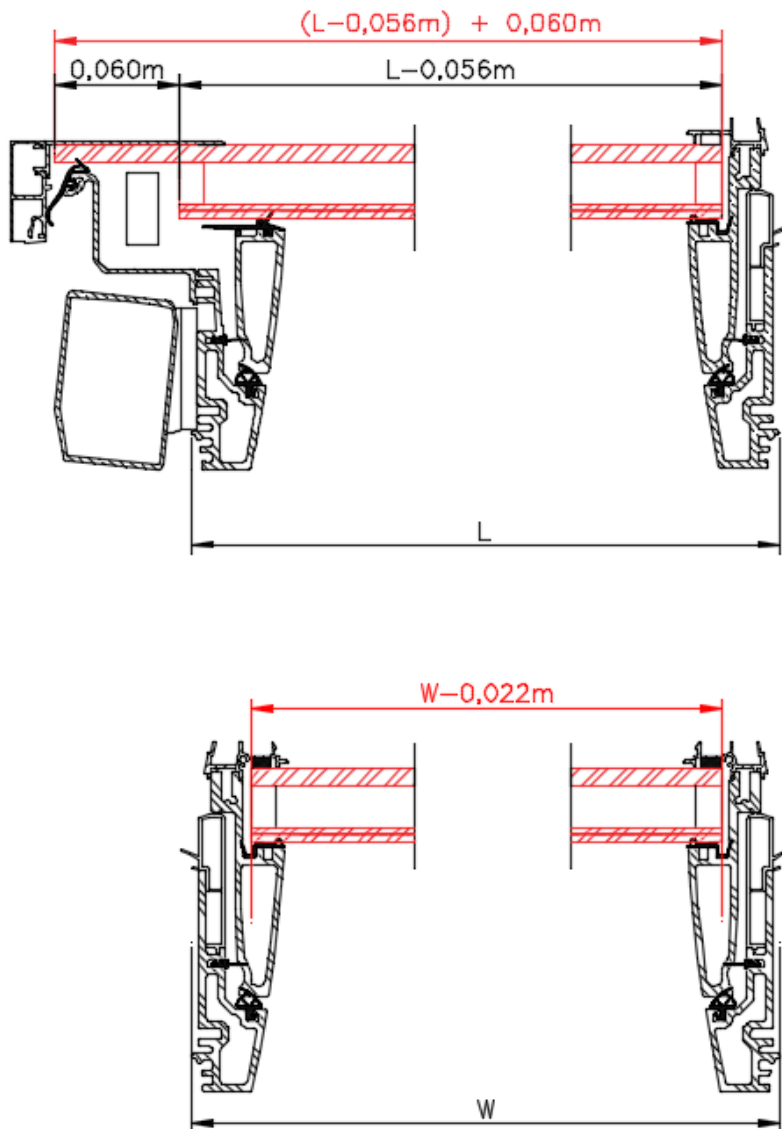
$$= ((2,4 - 0,056m) \cdot 0,014 + 0,060m \cdot 0,008m) \cdot (1,0 - 0,022m) \cdot 25 \text{ kN/m}^3 = 0,81 \text{ kN}$$

The weight of the openable window casement profile is set to:

$$g_{\text{case},k} = A_{\text{case}} \cdot \gamma_{\text{frame}} \cdot g = 8,57 \cdot 10^{-4} \text{ m}^2 \cdot 2076 \text{ kg/m}^3 \cdot 9,81 \text{ m/s}^2 = 0,017 \text{ kN/m}$$

Here, the area of the casement profiles (A_{case}) is taken from Annex C4 and the density (γ_{frame}) is taken from Annex D.1 in ETA-17/0467.

Figure 5: Glass dimension for openable window



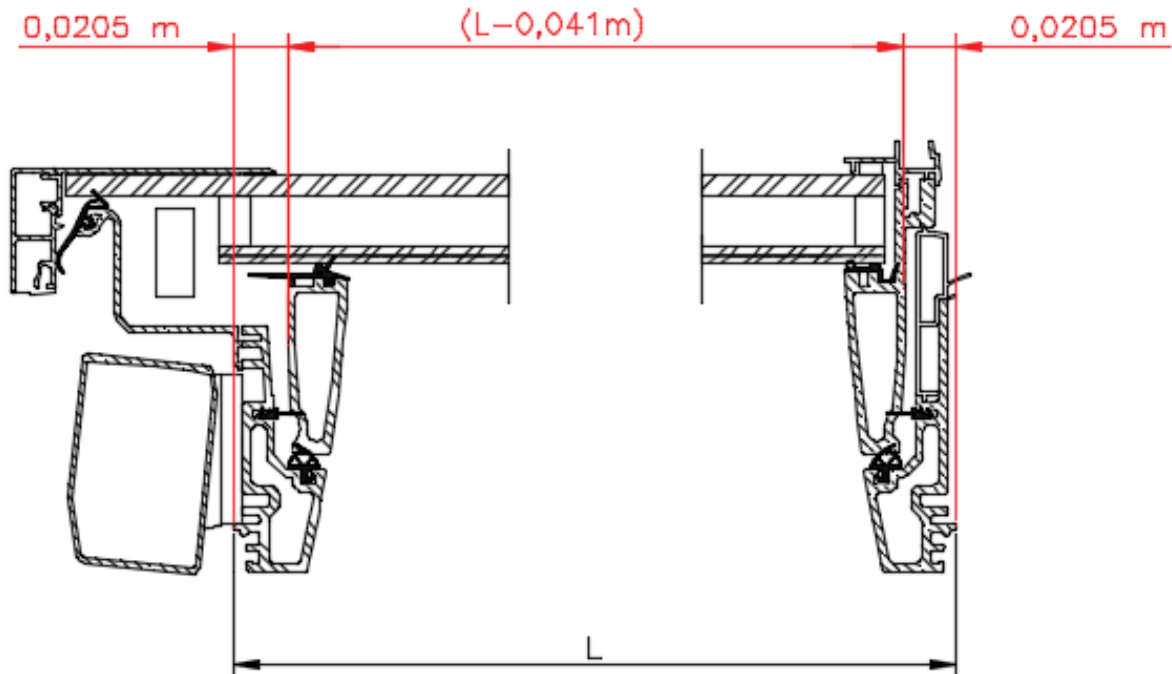
The perimeter of the casement L_{case} is found, see also Figure 6:

$$L_{case} = 2 \cdot (L - 0,041m) + 2 \cdot (W - 0,041m) = 2 \cdot (2,4 - 0,041m) + 2 \cdot (1,0 - 0,041m) = 6,64m$$

The total characteristic self-weight perpendicular to the openable window ($G_{\perp,k}$) is found to:

$$G_{\perp,k} = (G_{glass,k} + g_{case,k} \cdot L_{case}) \cdot \cos(\alpha) = (0,81kN + 0,017kN/m \cdot 6,64m) \cdot \cos(25^\circ) = 0,84kN$$

Figure 6: Dimension for casement profile for openable window



Glass area ($A_{W,suc}$) for which the wind suction acts upon:

$$A_{W,suc} = ((L - 0,056m) + 0,060m) \cdot (W - 0,022m) = ((2,4 - 0,056m) + 0,060m) \cdot (1,0 - 0,022m) = 2,35m^2$$

The characteristic wind suction perpendicular of the openable window ($Q_{s\perp,k}$) is found

$$Q_{s\perp,k} = q_{p,k} \cdot c \cdot A_{W,suc} = 0,8kN/m^2 \cdot 0,5 \cdot 2,35m^2 = 0,94kN$$

The load combination e) short term dominant wind, no snow load, is the worst case for wind suction on the window. Giving a total design load perpendicular to the window ($P_{\perp,d}$):

$$P_{\perp,d} = \gamma_{Q,1} \cdot Q_{s\perp,k} - \gamma_{G,inf} \cdot G_{\perp,k} = 1,5 \cdot 0,94kN - 1,0 \cdot 0,84kN = 0,57kN$$

The characteristic load bearing capacity (R_k) is taken from Clause 8, Table 6 for double glazing:

$$R_k = 8,87 kN$$

Reduction safety factor for short term: Dominant wind combination, no snow load, duration: 10 minutes, temperature: 60°C is found to:

$$e) \text{ factor} = \gamma_{MR} \cdot K_{t,10 \text{ min}} \cdot K_u \cdot K_{\theta,60} = 1,5 \cdot 1,1 \cdot 1,2 \cdot 1,5 = 2,97$$

Design load bearing capacity (R_d):

$$R_d = \frac{8,87kN}{2,97} = 2,99kN$$

$$\text{Utilization: } P_{\perp d}/R_d \cdot 100 = 0,57kN/2,99kN \cdot 100 = 19\%$$

Bending in frame and casement profile

The bending in frame and casement profile is in this example only calculated for the medium term dominate snow combination, hereby showing the calculations procedure. Normally all load combination should be investigated.

Design capacity of frame and casement, duration: 3 months, temperature: 20°C:

$$\sigma_{R,d} = \frac{\sigma_{R,k}}{\gamma_{MR} \cdot K_{t,3\text{ month}} \cdot K_u \cdot K_{\theta,20^\circ}} = \frac{1257N/mm^2}{1,2 \cdot 1,66 \cdot 1,2 \cdot 1,0} = 526N/mm^2$$

(For characteristic bending strength see Table 3, for partial safety factors see Table 8a/ULS and for magnification and reduction factors see Table 8b/ULS.)

The characteristic line load from self-weight perpendicular to the roof window is denoted $g_{p,k}$ and perpendicular line load from the characteristic snow pressure is denoted $s_{p,k}$. The corrected height is applied but the original angle is used:

$$g_{p,k} = \frac{G_{VR,k} \cdot \cos(\alpha)}{L_{cor}} = \frac{0,72 \cdot \cos(25)}{2,543} = 0,26kN/m, \text{ on each side frame/casement}$$

$$s_{p,k} = S_{s,k} \cdot \cos(\alpha) = 0,40kN/m \cdot \cos(25) = 0,36kN/m, \text{ on each side frame/casement}$$

$$M_d = \frac{1}{8} \cdot (\gamma_{G,sub} \cdot \xi_{G,sub} \cdot g_{p,k} + \gamma_{Q,1} \cdot s_{p,k}) \cdot L_{cor}^2$$

$$= \frac{1}{8} \cdot (1,35 \cdot 0,85 \cdot 0,26 + 1,5 \cdot 0,36)kN/m \cdot (2,543m)^2 = 0,68kNm$$

$$M_{frame,d} = M_d \cdot \frac{I_{frame}}{I_{frame} + I_{casement}} = 0,68kNm \cdot \frac{0,669 \cdot 10^6 mm^4}{0,669 \cdot 10^6 mm^4 + 0,930 \cdot 10^6 mm^4} = 0,28kNm$$

$$\sigma_{frame,d} \approx \frac{M_{frame,d}}{W_{y,frame}} = \frac{0,28 \cdot 10^6 Nmm}{9,93 \cdot 10^3 mm^3} = 28,7N/mm^2$$

$$\text{Utilization: } \frac{\sigma_{frame,d}}{\sigma_{R,d}} \cdot 100 = \frac{28,7N/mm^2}{526N/mm^2} \cdot 100 = 5,4\%$$

$$M_{casement,d} = M_d \cdot \frac{I_{casement}}{I_{frame} + I_{casement}} = 0,68kNm \cdot \frac{0,930 \cdot 10^6 mm^4}{0,669 \cdot 10^6 mm^4 + 0,930 \cdot 10^6 mm^4} = 0,40kNm$$

$$\sigma_{casement,d} \approx \frac{M_{casement,d}}{W_{y,casement}} = \frac{0,40 \cdot 10^6 Nmm}{16,4 \cdot 10^3 mm^3} = 24,1N/mm^2$$

$$\text{Utilization: } \frac{\sigma_{casement,d}}{\sigma_{R,d}} \cdot 100 = \frac{24,1N/mm^2}{526N/mm^2} \cdot 100 = 4,6\%$$

Here, the characteristic bending strength is taken from Annex D.1 in ETA-17/0467. Second moment of area and section modulus are taken from Annex C.1 and C.4 in ETA-17/0467. The rotation of the main axis is ignored, as it has little influence on the result, and the resulting stress is much lower than the bending strength.

Shear force in frame profile

The shear force in frame profile is in this example only calculated for the medium term dominate snow combination, hereby showing the calculations procedure. Normally all load combination shall be investigated.

Design capacity shear stress of frame, duration: 3 months, temperature: 20°C:

$$\tau_{frame,R,d} = \frac{\tau_{frame,R,k}}{\gamma_{MR} \cdot K_{t,3\text{ month}} \cdot K_u \cdot K_{\theta,20^\circ}} = \frac{53,8N/mm^2}{1,2 \cdot 1,66 \cdot 1,2 \cdot 1,0} = 22,5N/mm^2$$

(For characteristic shear strength see Table 3, for partial safety factors see Table 8a/ULS and for magnification and reduction factors see Table 8b/ULS.)

The shear force is generally taken in combination by the frame and casement profile, but near the ends of the roof window, the entire shear force is taken by the frame profile. The original angle is used. Largest shear force is in the right roof window in this example:

$$\begin{aligned} V_{frame} &= R_{V1R} \cdot \cos(\alpha) - R_{H1R} \cdot \sin(\alpha) \\ &= 1,83kN \cdot \cos(25) - 1,62kN \cdot \sin(25) \\ &= 0,97kN \end{aligned}$$

$$\tau_{frame} = \frac{V_{frame}}{A_{web}} \approx \frac{0,97 \cdot 10^3 N}{550mm^2} = 1,77N/mm^2$$

$$\text{Utilization: } \frac{\tau_{frame}}{\tau_{frame,R,d}} \cdot 100 = \frac{1,77N/mm^2}{22,5N/mm^2} \cdot 100 = 7,9\%$$

Here, the characteristic shear strength is taken from Annex D.1 and A_{web} from Annex C.1 in ETA-17/0467.

Deflection

Deflections are checked for each side separately and perpendicular to the corrected roof window angle. 6 SLS load combinations can therefore be made, for this load case:

g) Long term: Dominant self-weight:

$$G_{VR,k}$$

h) Medium term: Dominant snow:

$$G_{VR,k} + S_{V,k}$$

i) Short term: Dominant wind pressure, with snow:

$$G_{VR,k} + Q_{c,k} + \Psi_{0,snow} \cdot S_{V,k} \Rightarrow$$

$$G_{VR,k} + Q_{c,k} + 0,5 \cdot S_{V,k}$$

j) Short term: Dominant wind pressure, no snow

$$G_{VR,k} + Q_{c,k}$$

k) Short term: Dominant snow, with wind:

$$G_{VR,k} + \Psi_{0,wind} \cdot Q_{c,k} + S_{V,k} \Rightarrow$$

$$G_{VR,k} + 0,6 \cdot Q_{c,k} + S_{V,k}$$

l) Short term: Dominant wind suction, no snow

$$G_{VL,k} + Q_{s,k}$$

The factors to find the design value of the deflection of the frame/casement are found from the formula given in Clause 2 and Table 8b. Duration is divided up in long term (25 years), medium term (3 month) and short term (10 min), and temperature is taken for the highest it can be, 20°C when snow and 60°C when without snow. Hence self-weight is set to the lifespan of the window, snow duration is set to 3 months and wind duration set to 10 minutes. Snow duration may differ from region to region and should be changes accordingly.

Long term: Dominant self-weight combination, duration: 25 years, temperature: 60°C:

$$g) \text{ factor} = \gamma_{MC} \cdot C_{t,25 \text{ years}} \cdot C_u \cdot C_{\theta,60^\circ} = 1,1 \cdot 1,15 \cdot 1,2 \cdot 1,05 = 1,59$$

Medium term: Dominant snow combination, duration: 3 months, temperature: 20°C:

$$h) \text{ factor} = \gamma_{MC} \cdot C_{t,3 \text{ months}} \cdot C_u \cdot C_{\theta,20^\circ} = 1,1 \cdot 1,11 \cdot 1,2 \cdot 1,0 = 1,47$$

Short term: Dominant wind pressure combination, duration: 10 minutes, temperature: 20°C:

$$i) \text{ factor} = \gamma_{MC} \cdot C_{t,10 \text{ min}} \cdot C_u \cdot C_{\theta,20^\circ} = 1,1 \cdot 1,02 \cdot 1,2 \cdot 1,0 = 1,35$$

Short term: Dominant wind pressure combination, no snow load, duration: 10 minutes, temperature: 60°C:

$$j) \text{ factor} = \gamma_{MC} \cdot C_{t,10 \text{ min}} \cdot C_u \cdot C_{\theta,60^\circ} = 1,1 \cdot 1,02 \cdot 1,2 \cdot 1,05 = 1,41$$

Short term: Dominant snow combination, duration: 10 minutes, temperature: 20°C:

$$k) \text{ factor} = \gamma_{MC} \cdot C_{t,10 \text{ min}} \cdot C_u \cdot C_{\theta,20^\circ} = 1,1 \cdot 1,02 \cdot 1,2 \cdot 1,0 = 1,35$$

Short term: Dominant wind suction combination, no snow load, duration: 10 minutes, temperature: 60°C:

$$l) \text{ factor} = \gamma_{MC} \cdot C_{t,10 \text{ min}} \cdot C_u \cdot C_{\theta,60^\circ} = 1,1 \cdot 1,02 \cdot 1,2 \cdot 1,05 = 1,41$$

(For partial safety factors see Table 8a/SLS and for magnification and reduction factors see Table 8b/SLS).

Characteristic Self-weight perpendicular to the corrected roof window angle:

$$g_{p,cor,k} = \frac{G_V \cdot \cos(\alpha_{cor})}{L_{cor}} = \frac{0,72 \cdot \cos(24,3)}{2,543} = 0,26 \text{ kN/m}, \text{ on each side frame/casement}$$

Characteristic wind pressure and suction perpendicular to the corrected roof window angle:

$$q_{c,cor,k} = q_{c,k} \cdot \cos(-\Delta\alpha) = 0,2 \text{ kN/m} \cdot \cos(0,7) = 0,20 \text{ kN/m}, \text{ on each side frame/casement}$$

Characteristic snow load perpendicular to the corrected roof window angle:

$$s_{p,cor,k} = s_{s,k} \cdot \cos(\alpha_{cor})^2 = 0,40 \text{ kN/m} \cdot \cos(24,3) = 0,33 \text{ kN/m}, \text{ on each side frame/casement}$$

In the deflection calculations, the second moment of area are found in ETA-17/0467 Annex C.1 and Annex C.4 and for E-modulus see Table 3 including Note 3

g) Deflection for long term: Dominant self-weight

$$u = \frac{5}{384} \cdot \frac{(g_{p,cor,k}) \cdot L_{cor}^4}{E \cdot (I_{frame} + I_{casement})} \cdot \text{factor}_g$$

$$= \frac{5}{384} \cdot \frac{(0,26) \text{ N/mm} \cdot (2543 \text{ mm})^4}{41600 \text{ N/mm}^2 \cdot 0,83 \cdot (0,669 \cdot 10^6 \text{ mm}^4 + 0,930 \cdot 10^6 \text{ mm}^4)} \cdot 1,59 = 4,1 \text{ mm} < \frac{L_{cor}}{150} = 17 \text{ mm}$$

h) Deflection for medium term: Dominant snow

$$u = \frac{5}{384} \cdot \frac{(g_{p,cor,k} + s_{p,cor,k}) \cdot L_{cor}^4}{E \cdot (I_{frame} + I_{casement})} \cdot \text{factor}_h$$

$$= \frac{5}{384} \cdot \frac{(0,26 + 0,33) \text{ N/mm} \cdot (2543 \text{ mm})^4}{41600 \text{ N/mm}^2 \cdot 0,83 \cdot (0,669 \cdot 10^6 \text{ mm}^4 + 0,930 \cdot 10^6 \text{ mm}^4)} \cdot 1,47 = 8,6 \text{ mm} < \frac{L_{cor}}{150} = 17 \text{ mm}$$

i) Deflection for short term: Dominant wind pressure, with snow:

$$u = \frac{5}{384} \cdot \frac{(g_{p,cor,k} + q_{c,cor,k} + \Psi_{0,snow} \cdot s_{p,cor,k}) \cdot L_{cor}^4}{E \cdot (I_{frame} + I_{casement})} \cdot f_{actor,i}$$

$$= \frac{5}{384} \cdot \frac{(0,26 + 0,20 + 0,5 \cdot 0,33) N/mm \cdot (2543 mm)^4}{41600 N/mm^2 \cdot 0,83 \cdot (0,669 \cdot 10^6 mm^4 + 0,930 \cdot 10^6 mm^4)} \cdot 1,35 = 8,3 mm < \frac{L_{cor}}{150} = 17 mm$$

j) Deflection for short term: Dominant wind, without snow:

$$u = \frac{5}{384} \cdot \frac{(g_{p,cor,k} + q_{c,cor,k}) \cdot L_{cor}^4}{E \cdot (I_{frame} + I_{casement})} \cdot f_{actor,j}$$

$$= \frac{5}{384} \cdot \frac{(0,26 + 0,20) N/mm \cdot (2543 mm)^4}{41600 N/mm^2 \cdot 0,83 \cdot (0,669 \cdot 10^6 mm^4 + 0,930 \cdot 10^6 mm^4)} \cdot 1,41 = 6,4 mm < \frac{L_{cor}}{150} = 17 mm$$

k) Deflection for short term: Dominant snow, with wind:

$$u = \frac{5}{384} \cdot \frac{(g_{p,cor,k} + \Psi_{0,wind} \cdot q_{c,cor,k} + s_{p,cor,k}) \cdot L_{cor}^4}{E \cdot (I_{frame} + I_{casement})} \cdot f_{actor,k}$$

$$= \frac{5}{384} \cdot \frac{(0,26 + 0,6 \cdot 0,20 + 0,33) N/mm \cdot (2543 mm)^4}{41600 N/mm^2 \cdot 0,83 \cdot (0,669 \cdot 10^6 mm^4 + 0,930 \cdot 10^6 mm^4)} \cdot 1,35 = 9,5 mm < \frac{L_{cor}}{150} = 17 mm$$

l) Deflection for short term: Dominant wind suction, without snow:

Since the self-weight is larger than the wind suction, the combination with wind suction as is not investigated. Please note that for a suction load, only the second moment of area of the casement is used when calculating the deflection for an openable window.