1. Basic data

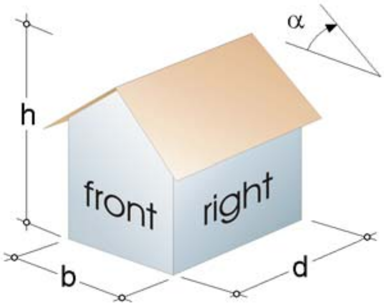
BUILDING PROJECT:	**Hangar in Frankfurt EC**		
STANDARD:	Eurocode:	wind:	DIN EN 1991-1-4:2010-12 in conjunction with National Annex "Deutschland" here: DIN EN 1991-1-4:2010-12/NA (protected) subsequently named EC1-1-4
		snow:	DIN EN 1991-1-3:2010-12 in conjunction with National Annex "Deutschland" here: DIN EN 1991-1-3:2010-12/NA (protected) subsequently named EC1-1-3

LOCATION:	Frankfurt am Main, Stadt
AMTL. GEMEINDESCHLÜSSEL:	06412000
TYPE:	Kreisfreie Stadt
DISTRICT:	Frankfurt am Main
FEDERAL STATE:	Hessen

ALT. ABOVE SEA LEVEL:	98 m	
WIND ZONE:	1	⇒ $v_{b,0}$ = 28.00 m/s
SNOW LOAD ZONE:	1	⇒ s_k = 0.65 kN/m²

2. Wind actions

2.1 Input data



building model:
type: symmetric double pitch roof
h = 11.00 m
b = 30.00 m
d = 40.00 m
α = 10.00 °

loc.: inland
orography: general rule

protr. roofs	front	right	back	left
in m	0.00	0.00	0.00	0.00

2.2 Height-dependent peak velocity pressure

peak velocity pressures

z = height above ground, $v_{mf}(z)$ and $I_{vf}(z)$ acc. to EC1-1-4/NA Tab NA.B.2 resp. NA.B.4, $v_m(z)$ acc. to (NA.B.9), $I_v(z)$ acc. to (NA.B.10)
peak velocity pressures $q_p(z)$ acc. to (NA.B.11) mit ρ = 1.25 kg/m³, orography factor: $c_o(z)$ = 1.0 (general rule)

z m	$v_{mf}(z)$ m/s	$I_{vf}(z)$ -	$v_m(z)$ m/s	$I_v(z)$ -	$q_p(z)$ kN/m2
11.00	24.66	0.215	24.66	0.215	0.87

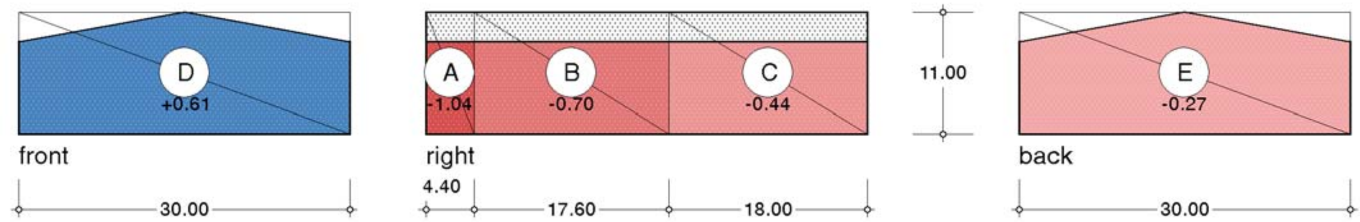
2.3 Wind from front side

characteristic values: e = min(b, 2h) = 22.00 m type: e < d h/d = 0.28

2.3.1 Loading of vertical walls (wind from front side)

external pressure coefficients and load ordinates acc. to EC1-1-4 / Tab. 7.1
ordinate = $c_{pe,10}$ * q(h), (+) = pressure

area	A	B	C	D	E	note
$c_{pe,10}$	-1.20	-0.80	-0.50	+0.70	-0.31	interpolated
ordinates	**-1.04**	**-0.70**	**-0.44**	**+0.61**	**-0.27**	kN/m²



the values described here in level of the roof edge are also effective for the lower surface of the roof area in the region of protruding roofs

2.3.2 Increased wind actions on vertical walls (wind from front side)

for reckoning of connections and verification of details

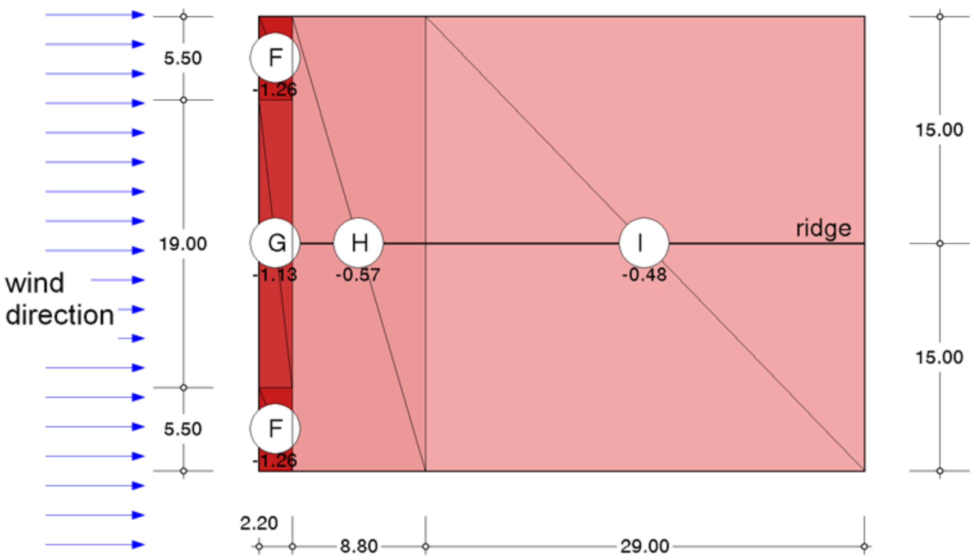
logarithmically interpolated external pressure coefficients depending on predefined loaded areas A_i acc. to EC1-1-4 / 7.2.1
ordinate = $c_{pe,Ai}$ * q(h), (+) = pressure

area	A	B	C	D	E	note
loaded area A1 = 1.00 m²						
Cpe,A1	-1.40	-1.10	-0.50	+1.00	-0.50	interpolated
ordinates	**-1.22**	**-0.96**	**-0.44**	**+0.87**	**-0.44**	kN/m²

2.3.3 Loading of roof area (wind from front side)

external pressure coefficients and load ordinates for duopitch roofs acc. to EC1-1-4 / Tab. 7.4b (Θ=90°)
ordinate = $c_{pe,10}$ * q(h), (+) = pressure

area	F	G	H	I	J	note
Cpe,10	-1.45	-1.30	-0.65	-0.55	-	interpolated
ordinates	**-1.26**	**-1.13**	**-0.57**	**-0.48**	-	kN/m²



2.3.4 Increased suction loads on roof area (wind from front side)

for reckoning of connections and verification of details

logarithmically interpolated external pressure coefficients depending on predefined loaded areas A_i acc. to EC1-1-4 / 7.2.1
ordinate = $c_{pe,Ai}$ * q(h). Here only the suction loads(-) are shown. If the preceding table additionally contains pressure loads (+) these are effective also for reckoning of connections and verification of details.

area	F	G	H	I	J	note
loaded area A1 = 1.00 m²						
Cpe,A1	-2.10	-2.00	-1.20	-0.55	-	interpolated
ordinates	**-1.83**	**-1.74**	**-1.04**	**-0.48**	-	kN/m²

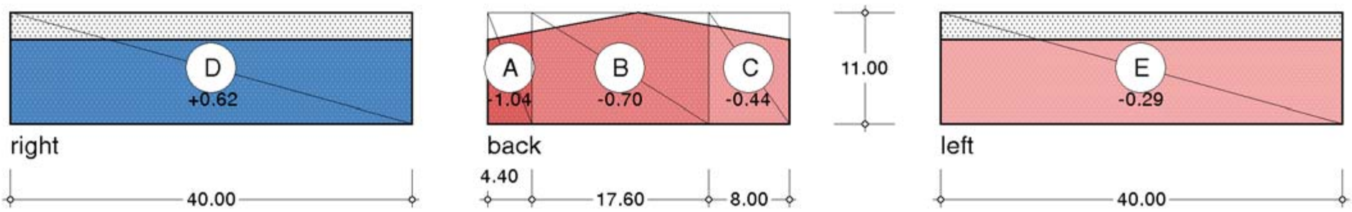
2.4 Wind from righthand

characteristic values: e = min(d, 2h) = 22.00 m type: e < b h/b = 0.37

2.4.1 Loading of vertical walls (wind from righthand)

external pressure coefficients and load ordinates acc. to EC1-1-4 / Tab. 7.1
ordinate = $c_{pe,10}$ * q, (+) = pressure

area	A	B	C	D	E	note
$c_{pe,10}$	-1.20	-0.80	-0.50	+0.72	-0.33	interpolated
ordinates	**-1.04**	**-0.70**	**-0.44**	**+0.62**	**-0.29**	kN/m²



the values described here in level of the roof edge are also effective for the lower surface of the roof area in the region of protruding roofs

2.4.2 Increased wind actions on vertical walls (wind from righthand)
for reckoning of connections and verification of details

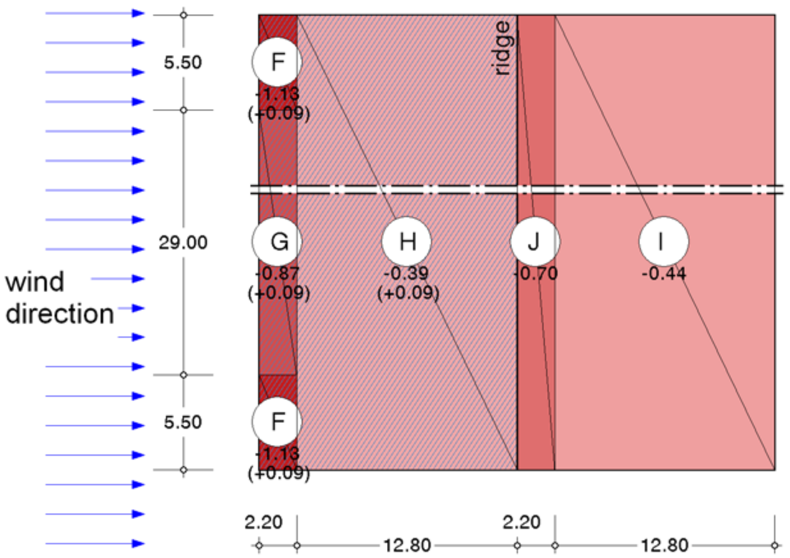
logarithmically interpolated external pressure coefficients depending on predefined loaded areas A_i acc. to EC1-1-4 / 7.2.1
ordinate = $c_{pe,Ai}$ * q(h), (+) = pressure

area	A	B	C	D	E	note
loaded area A1 = 1.00 m²						
$c_{pe,A1}$	-1.40	-1.10	-0.50	+1.00	-0.50	interpolated
ordinates	**-1.22**	**-0.96**	**-0.44**	**+0.87**	**-0.44**	kN/m²

2.4.3 Loading of roof area (wind from righthand)

external pressure coefficients and load ordinates for duopitch roofs acc. to EC1-1-4 / Tab. 7.4a (Θ=0°)
ordinate = $c_{pe,10}$ * q(h), (+) = pressure

area	F	G	H	I	J	note
$c_{pe,10}$	-1.30	-1.00	-0.45	-0.50	-0.80	interpolated
alternative	+0.10	+0.10	+0.10	-	-	interpolated
ordinates	**-1.13**	**-0.87**	**-0.39**	**-0.44**	**-0.70**	kN/m²
alternative	**+0.09**	**+0.09**	**+0.09**	-	-	kN/m²



2.4.4 Increased suction loads on roof area (wind from righthand)

for reckoning of connections and verification of details

logarithmically interpolated external pressure coefficients depending on predefined loaded areas A_i acc. to EC1-1-4 / 7.2.1
ordinate = $c_{pe,Ai}$ * q(h). Here only the suction loads(-) are shown. If the preceding table additionally contains pressure loads (+)
these are effective also for reckoning of connections and verification of details.

area	F	G	H	I	J	note
loaded area A1 = 1.00 m²						
$c_{pe,A1}$	-2.25	-1.75	-0.75	-0.50	-1.05	interpolated
ordinates	**-1.96**	**-1.52**	**-0.65**	**-0.44**	**-0.91**	kN/m²

2.5 Internal pressure

2.5.1 Specification of openings

face	opening area
front	A_{iv} = 0.00 m²
right	A_{ir} = 5.00 m²
back	A_{ih} = 0.00 m²
left	A_{il} = 5.00 m²

2.5.2 Internal pressure ordinates

determination of load ordinates acc. to EC1-1-4 par. 7.2.9; internal pressure values c_{pi} acc. to fig. 7.13; w = c_{pi} * q(h); (+ = pressure)

wind from front h/d = 0.28

$$\mu = \frac{A_{ir}+A_{ih}+A_{il}}{\sum A} = 1.00 \Rightarrow c_{pi} = -0.31 \qquad w_i = -0.27 \text{ kN/m}^2$$

wind from right h/d = 0.37

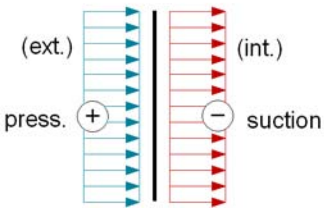
$$\mu = \frac{A_{ih}+A_{il}+A_{iv}}{\sum A} = 0.50 \Rightarrow c_{pi} = 0.2/-0.3 \qquad w_i = 0.17/-0.26 \text{ kN/m}^2$$

wind from behind h/d = 0.28

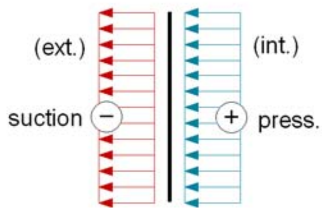
$$\mu = \frac{A_{il}+A_{iv}+A_{ir}}{\sum A} = 1.00 \Rightarrow c_{pi} = -0.31 \qquad w_i = -0.27 \text{ kN/m}^2$$

wind from left h/d = 0.37

$$\mu = \frac{A_{iv}+A_{ir}+A_{ih}}{\sum A} = 0.50 \Rightarrow c_{pi} = 0.2/-0.3 \qquad w_i = 0.17/-0.26 \text{ kN/m}^2$$



The load ordinates w_i shown here have to be superponed with the external load ordinates if they - how sketched - are acting in the same direction.

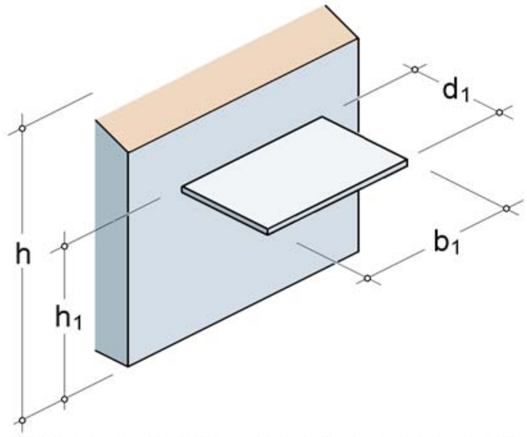


2.6 Wind actions on canopy

geometry

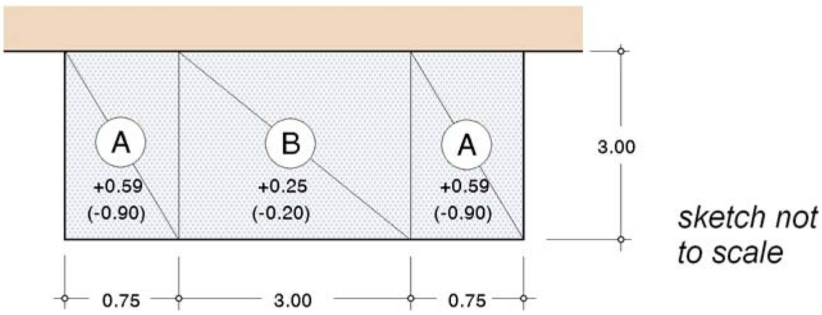
b_1 = 4.50 m
d_1 = 3.00 m
h_1 = 4.00 m
h = 10.00 m

h is the mean height of the main building



Load determination acc. to Muster-Liste der Technischen Baubestimmungen vom Februar 2007 - Anlage 1.1/1 - Absatz 4. This is substantially corresponding to annex NA.V of the German National Annex of DIN EN 1991-1-4/NA:2010-12 to Eurocode - and therefore is Eurocode in Germany.

$e = \min(d_1/4, b_1/2) =$ 0.75 m $q(h) = 0.84$ kN/m²



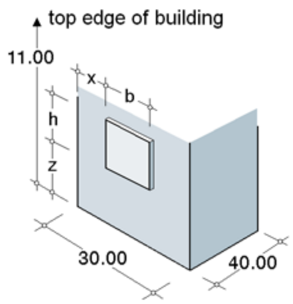
sketch not to scale

pressure values and load ordinates for canopy roofs				
load direct.	downw. (+)		upward (-)	
area	A	B	A	B
$c_{p.net}$	+0.70	+0.30	-1.07	-0.24
ordinates	+0.59	+0.25	-0.90	-0.20

interpolated kN/m²

ordinate $= c_{p,net}\, q(h)$

2.7 min/max resultant on cladding units



The determination of the resultant is done by integration (acc. to EC1-1-4 par. 7.2.2) of the range dependant calculated pressure/suction ordinates over the area of the cladding units. In so doing the respectively most unfavourable wind directions are considered.

$c_{pe,A}$ (A = frontage area with 1 < A < 10) is used as pressure coefficient.

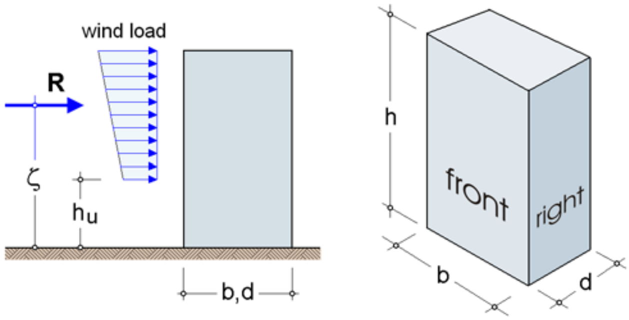
If the cladding unit is located in several areas with different load ordinates, the resultant is no longer acting in the centroid of the cladding unit. The depending eccentricities are recorded as Δx resp. Δz (horizontal resp. vertical distance from frontage centroid.

results

If in column T an X is recorded, the width and depth of the building were exchanged for the depending cladding unit. Then the result is effective for a cladding unit on the long side of the building.

Nr.	x	b	z	h	T	press.	Δx_D	Δz_D	suc.	Δx_S	Δz_S
-	m	m	m	m	-	kN	cm	cm	kN	cm	cm
1	0.00	0.00	0.00	0.00	-	**0.000**	0	0	**0.000**	0	0

2.8 Resultant wind force



h = 11.000 m
b = 30.000 m
d = 40.000 m

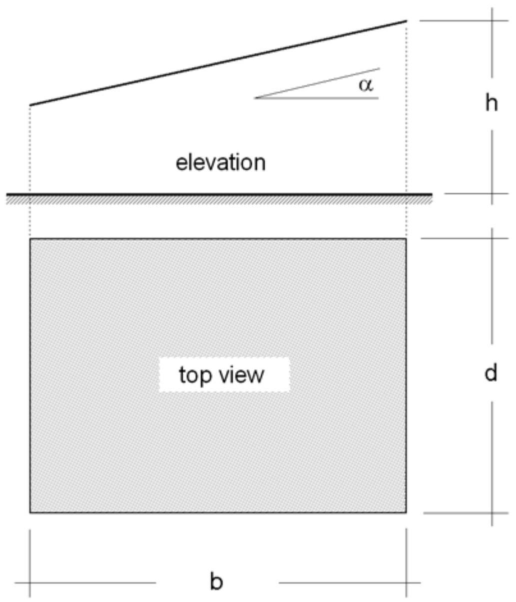
h_u = 0.000 m

results

The determination of the resultant wind force is done acc. to EC1-1-4 par. 5.3 and 7.6. The roof shape is not considered. The structural factor $c_s c_d$ is taken as 1.0.

wind from front side			wind from righthand			acc. to EC1-1-4
h/d	=	0.28	h/b	=	0.37	
d/b	=	1.33	b/d	=	0.75	
$c_{f,0}$	=	1.94	$c_{f,0}$	=	2.35	7.6 (fig. 7.23)
λ	=	0.73	λ	=	0.55	7.13 (Tab 7.16)
Ψ_λ	=	0.63	Ψ_λ	=	0.63	7.13 (fig. 7.36)
ζ	=	6.60 m	ζ	=	6.60 m	irrelevant
q(h)	=	0.87 kN/m²	q(h)	=	0.87 kN/m²	7.6 (2) and 4.5
A_{ref}	=	330.00 m²	A_{ref}	=	440.00 m²	7.6 (2)
R	**=**	**351.10 kN**	**R**	**=**	**566.94 kN**	$c_{f,0}\ \Psi_\lambda\ q(h)\ A_{ref}$

2.9 Canopy roof



2.9.1 System

type: monopitch roof

h = 8.00 m

b = 30.00 m

d = 20.00 m

α = 5.00 m

blockage: φ = 0.0000

surface : smooth

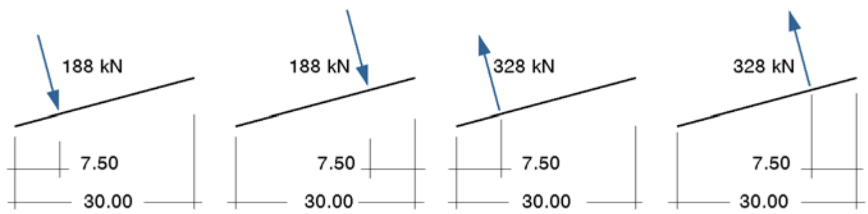
⇒ friction coefficient = 0.01

Determination of loads acc. to
EN 1991-1-4:2010-12 (Eurocode) par.
7.3 canopy roofs and
7.5 friction coefficients

2.9.2 Resultant wind force and arrangements of loads

φ	**Fo** all	**Fu** 0
c_f	+0.40	-0.70
F	+188	-328

$F = c_f\ q(h)\ A_{ref}$ mit q(h) = 0.78 kN/m und $A_{ref} = b\ d / \cos\alpha$ = 602.29 m²
Furthermore a resultant force from friction should be placed in roof surface in unfavourable direction: $F_{Friction} = 0.01 \cdot 2 \cdot A_{ref} \cdot q(h)$ = **9.35 kN**



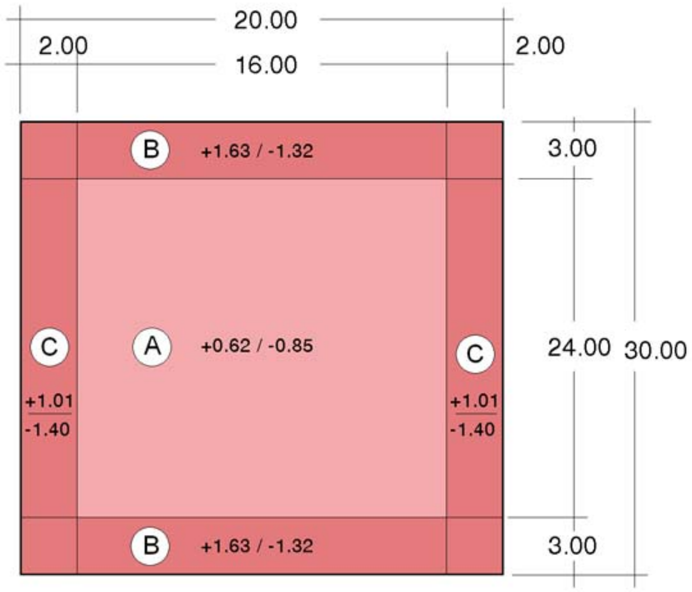
2.9.3 Pressure distribution for design of roof elements and fixings

areas	A	B	C
$c_{pe,net}$	+0.80	+2.10	+1.30
q(+)	**+0.62**	**+1.63**	**+1.01**
$c_{pe,net}$	-1.10	-1.70	-1.80
q(-)	**-0.85**	**-1.32**	**-1.40**

$q = c_{pe,net}\, q(h)$

+ values indicate a downward acting wind action

- values indicate an upward acting wind action



division of the roof area

sketch not to scale

3. Snow loads

3.1 Basic loading

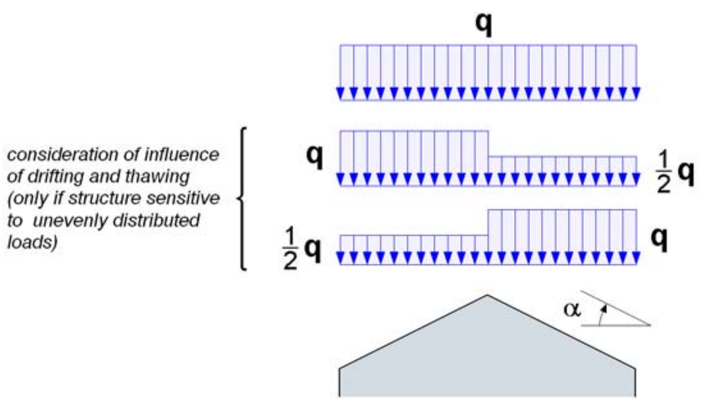
symmetrical duopitch roof

α = 10.00 °

μ_1 = 0.80

q = 0.52 kN/m²

$\frac{1}{2}$**q** = 0.26 kN/m²



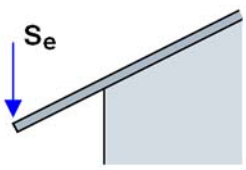
note: in case of layout of snowguards μ is 0.8.

3.2 Protruding roof

The design of those parts of a roof cantilevered out beyond the walls should take account of snow overhanging the edge of the roof, in addition to the load on that part of the roof.

$$S_e = 0.4\,(\mu_1 s_k)^2/\gamma = \underline{\underline{0.04\ \text{kN/m}}}$$

(γ = 3.0 kN/m³)



acc. to EC 1-1-3 / par. 6.3 in conjunction with NA-DE (NDP to 6.3)

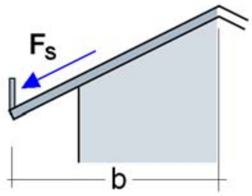
3.3 Snowguard

In case of placing of snowguards or other obstacles a force F_S should be taken as

$F_S = \bar{\mu}_1 \, s_k \, b \, \sin\alpha \; = \;$ 0.90 kN/m

$(\bar{\mu}_1 = 0.8)$

with $b = $ 10.00 m



3.4 Loading from roof abutting to taller construction works

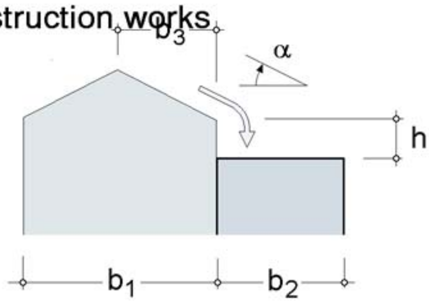
h = 1.20 m

b_1 = 12.00 m

b_2 = 8.00 m

b_3 = 6.00 m

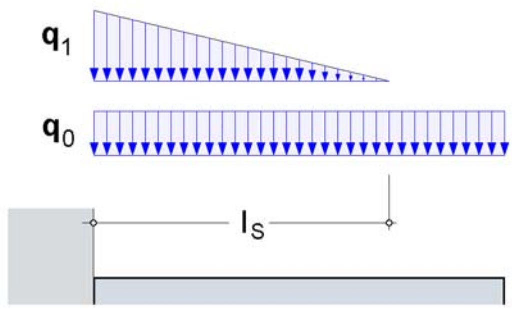
α = 30.00 °



length	$l_S = 5 \le 2h \le 15$	=	5.00 m
sliding snow load	$\mu_S = 0.8 \, b_3 / l_S$	=	0.96
drift	$\mu_{W1} = (b_1 + b_2) / 2h$	=	8.33
(with $\gamma = 2$ kN/m^3)	$\mu_{W2} = \gamma \, h / s_k - \mu_S$	=	2.73
	$\mu_W = \min(\mu_{W1}, \mu_{W2})$	=	2.73
total	$\mu_h = \mu_{min} \le \mu_S + \mu_W \le \mu_{max}$	=	2.00
load values	$\mathbf{q}_0 = \mu_1(0) \, s_k$	=	0.52 kN/m²
	$\mathbf{q}_1 = \mu_h \, s_k - \mathbf{q}_0$	=	0.78 kN/m²

μ_{max} = 2,0 (vgl. NA-DE: NA.6 - "Räumung zugänglich, seitlich offenes Vordach")

principle sketch



3.5 Drift

$h \;=\; 1.50$ m

$\mu_1 = 0.8$

$\mathbf{q_1} = \mu_1 s_k \quad = 0.52$ kN/m²

$\mu_2 = 0.8 \leq \gamma h / s_k \leq 2.0 = 2.00$

$\mathbf{q_2} = (\mu_2 - \mu_1)\, s_k \quad = 0.78$ kN/m²

$l_S = 5 \leq 2h \leq 15 \quad = 5.00$ m