RUHR-UNIVERSITÄT BOCHUM

RUB

EN 1990: Basis of Structural Design
EN 1991: Action on structures
Example

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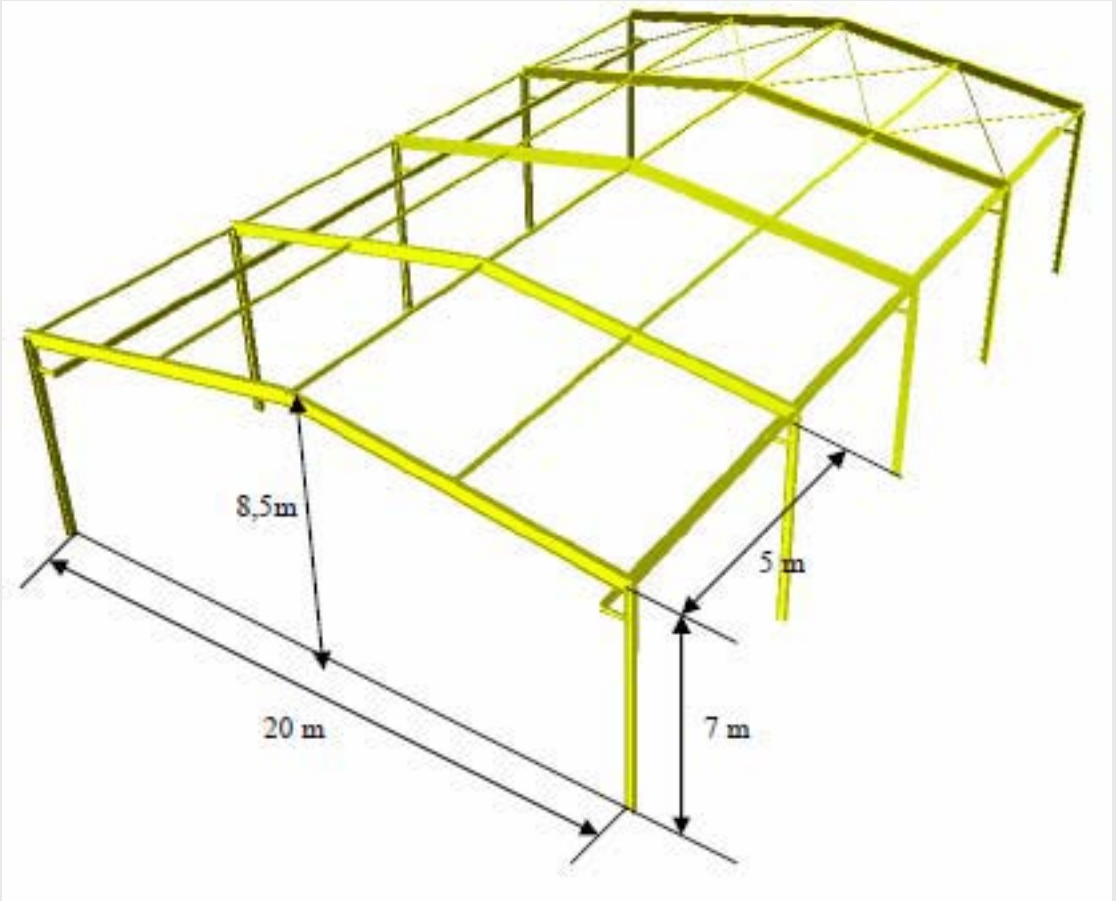
Structural system of the building

- single storey industrial hall
- 20 m wide, 20 m long
- 5 single bay portal frames
- columns 7 m height, 8,5 m at roof ridge
- crane runway girders at 6m height
- columns HEA 400,
  beams IPE 550,
  crane girders I 60,
  consoles I 280,
  wind bracing H 60x60x6
- construction steel S 235



Definition of the characteristic values

1. Permanent actions

1.1 Self weight of structural members:

γ: the mean value of the specific weight of steel, 78,5 kN/m3 (EN 1991-1-1, Appendix A).

the distributed self weight per unit length of members:

$g_k = \gamma A$,

A is the cross-sectional area

Element	Section	g_k [kN/m]
portal column	HEA 400	1,25
portal beam	IPE 550	1,05
purlin	HEA 200	0,42
crane girder	I 260	0,42
console	I 280	0,48
wind bracing	H 60x60x6	0,05

1.2 Roof and wall cladding

distributed load h = 0,3 kN/m^2

Line load due to self weight

$g_{roof} = g_{wall}$ = 5 m x 0,3 kN/m^2 = 1,5 kN/m

Definition of the characteristic values (cont.-d)

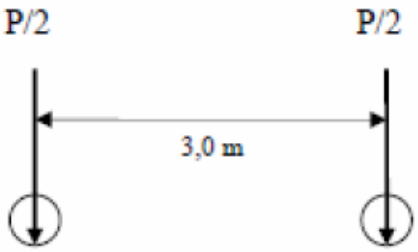
2. Imposed loads

2.1 Imposed loads on roofs

For roof category H 'roof not accessible except for normal maintenance and repair' (EN 1991-1-1, Table 6.9) the distributed and concentrated loads are

q_k = 0,4 kN/m^2, Q_k = 1,0 kN

p_{roof} = 5 m x 0,4 kN/m^2 = 2,0 kN/m on the girder



2.2 Actions imposed by the crane

P_{max} = 180 kN, P_{min} = 60 kN including dynamic effects.

Horizontal force due to the movement of the crane: H_x = 0,1 P.

Position of the crane: the centerline between the wheels is in the plane of the frame.

Definition of the characteristic values (cont.-d)

2.3 **Snow load**

2.3.1 The characteristic value of ground snow load s_k = *1,88 kN/m²*

2.3.2 The exposure coefficient C_e = *1,0 ('wind swept' or 'sheltered' conditions do not apply)*

2.3.3 Thermal coefficient C_t= *1,0 (normal thermal roof insulation is assumed)*

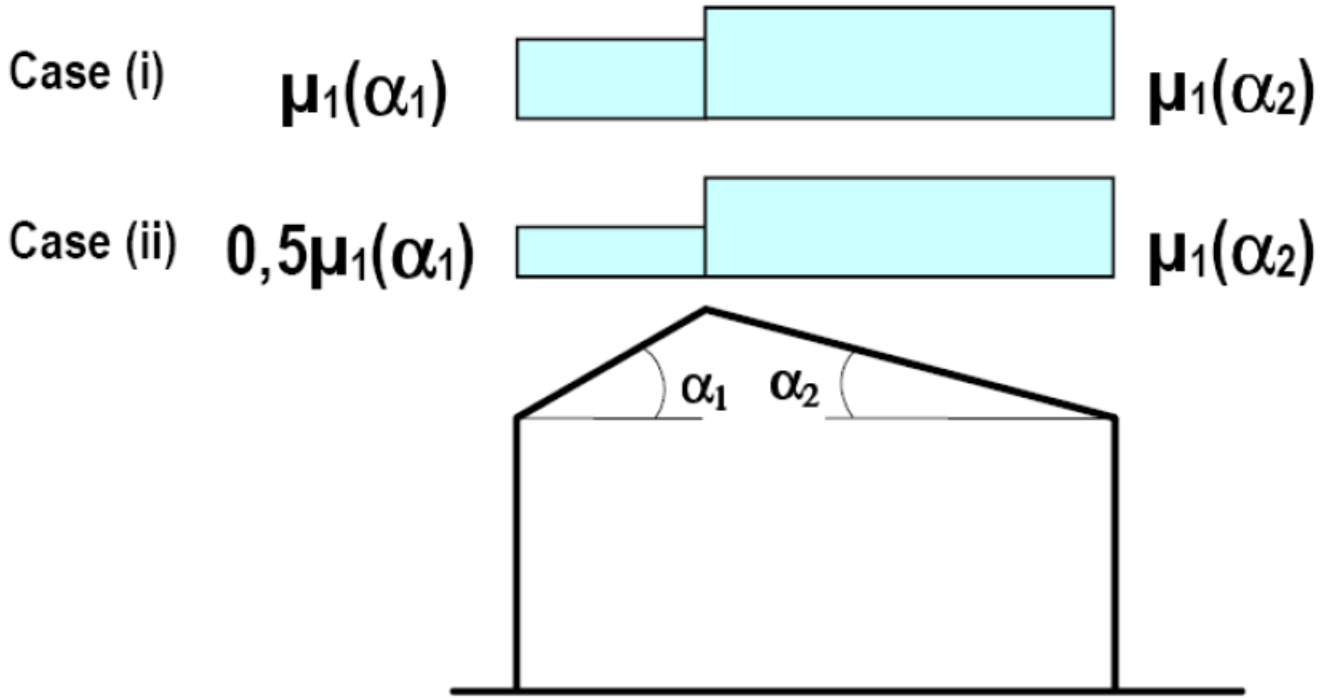
2.3.4 The snow load shape coefficients μ *depend on the roof angle* α
For 'duopitched' roof with $\alpha = 8{,}5°$: $\mu_1 = \mu_2 = 0{,}8$.

2.3.5 The snow load s_{roof}
$s_{roof} = \mu_1 \times C_e \times C_t \times s_k = 0{,}8 \times 1{,}0 \times 1{,}0 \times 1{,}88 = 1{,}5\ kN/m^2$
and the snow load *s on the girder*
$s = s_{roof} \times W = 1{,}5 \times 5 = 7{,}5\ kN/m$

2.3.6 Two snow load arrangements
are considered (according to EN 1991-1-3)

Definition of the characteristic values (cont.-d)

2.3 Snow load (cont.-d)



Definition of the characteristic values (cont.-d)

2.4 **Wind load**

2.4.1 Fundamental basic wind velocity $v_{b,0}$ = 25 m/s (wind map, national annex to EN 1991-1-4).

2.4.2 Basic wind velocity v_b (with usual values for directional and seasonal factors) :

$v_b = v_{b,0} \cdot c_{dir} \cdot c_{sea} = 25 \cdot 1{,}0 \cdot 1{,}0 = 25$ *m/s*

2.4.3 Mean wind velocity $v_m(z)$ *at reference height* $z_e = 8{,}5$ *m*

$v_m(z) = c_r(z) \cdot c_o(z) \cdot v_b = 18{,}4$ *m/s*

with orography factor $c_o(z) = 1$, *roughness factor* $c_r(z) = k_r \cdot \ln(z/z_0)$ terrain category III (suburban or industrial areas): $I_v = 0{,}22$, $z_0 = 0{,}3$

2.4.4 Peak velocity pressure $q_p(z)$

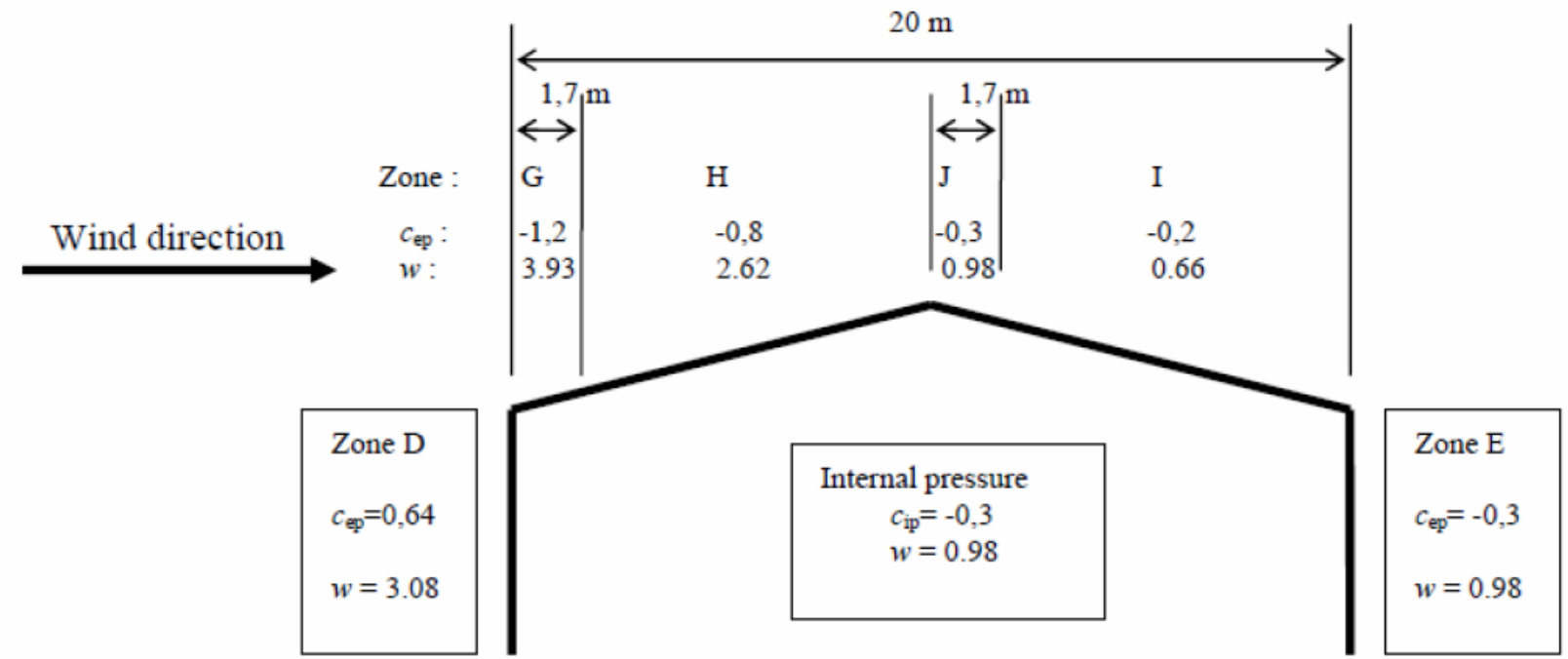
$q_p(z) = \{1+7\, I_v / [c_o(z) \ln(z/z_0)]\}\ ½\ \rho\ v_m(z) = 0{,}655$ *kN/m2*

with air density $\rho = 1{,}25$ *kg/m*^{3} *and turbulence intensity* $I_v = 1{,}0$

2.4.5 External c_{pe} *and internal* c_{pi} *wind pressure coefficients and* wind load *w:* $w = (c_{pe} - c_{pi})\ q_p$

Definition of the characteristic values (cont.-d)

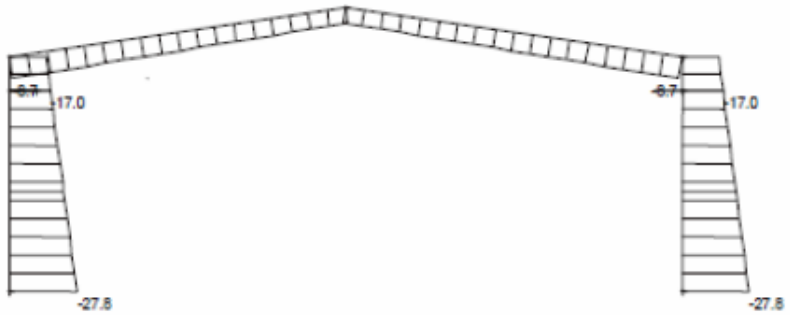
2.3 Wind load (cont.-d)



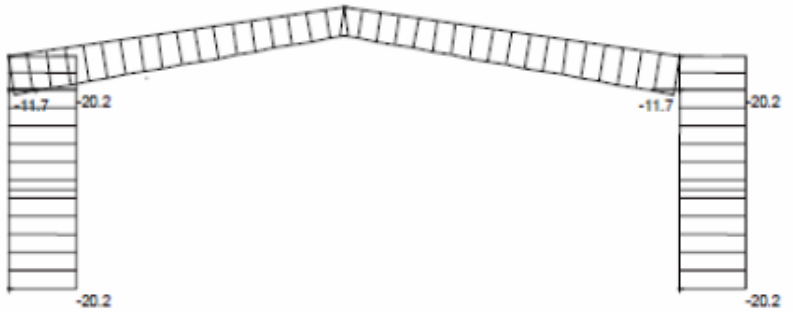
Internal forces due to actions

Internal axial forces:

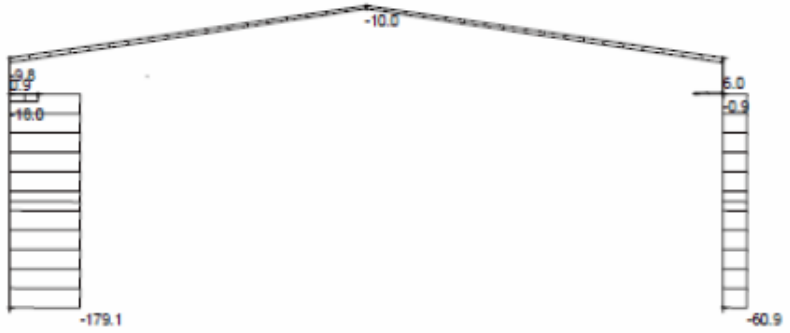
Self weight, roof and wall cladding



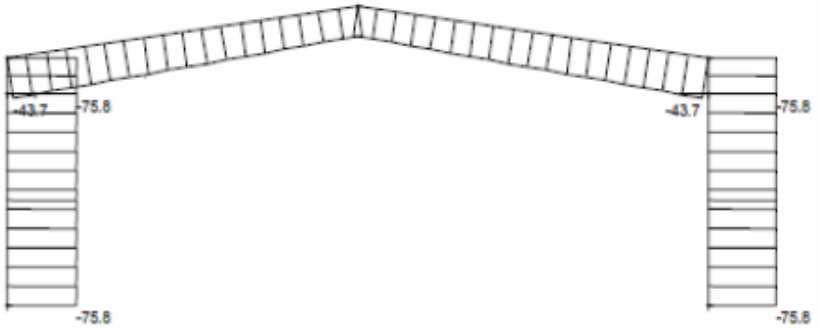
Imposed load: roof, wall



Crane: vertical load and horizontal side load

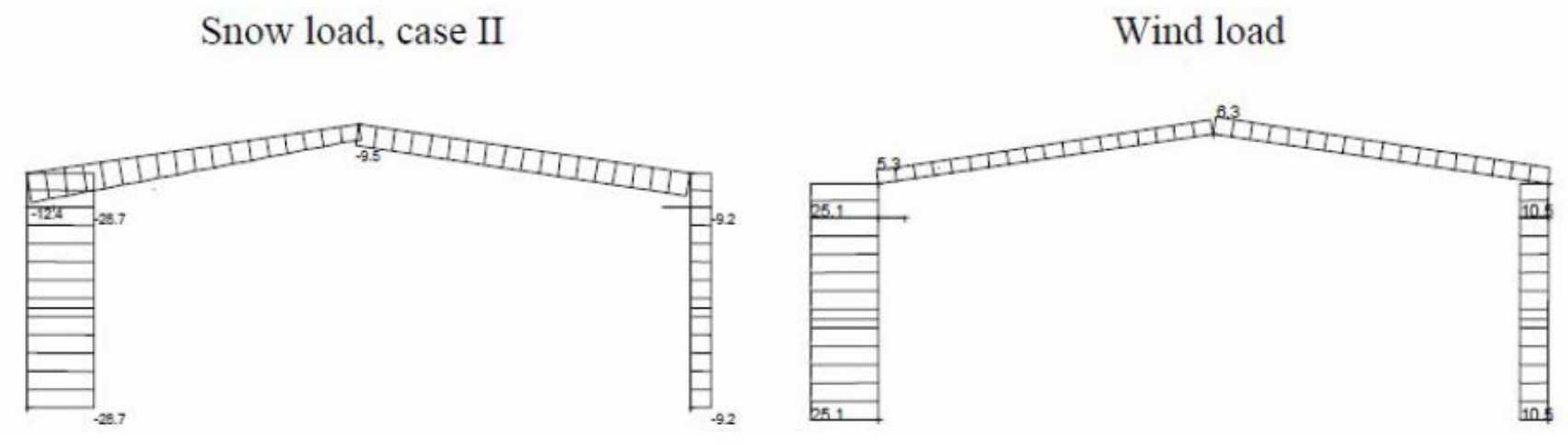


Snow load, case I



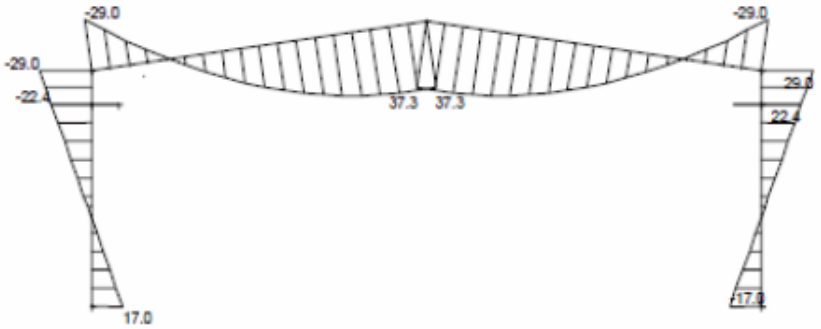
Internal forces due to actions (cont.-d)

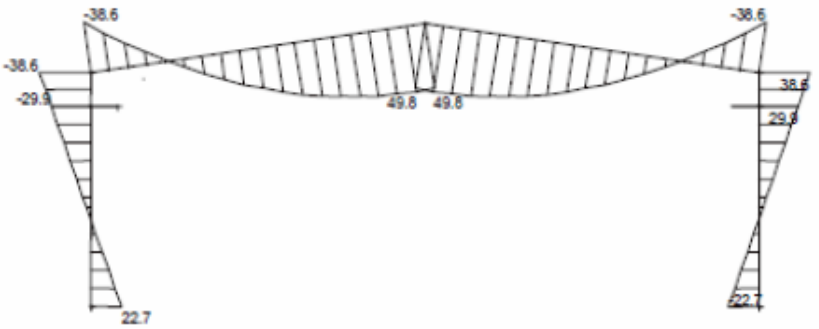
Axial forces (cont'd):



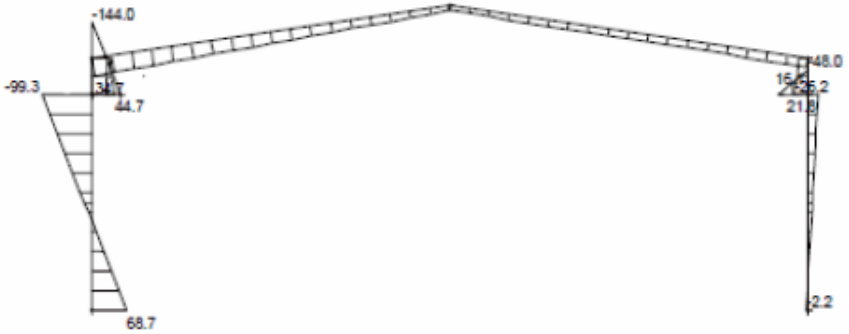
Internal forces due to actions (cont.-d)

Bending moments:

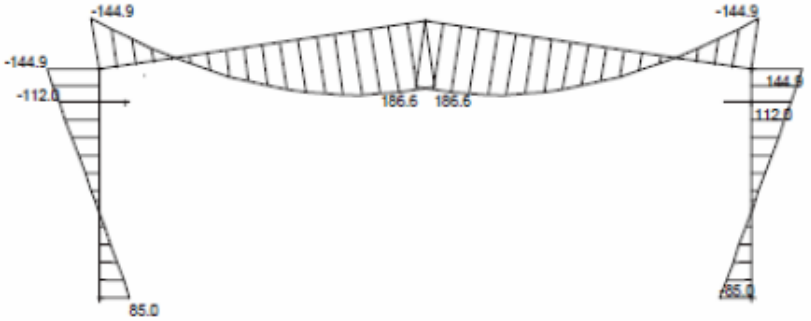




Crane: vertical load and horizontal side load



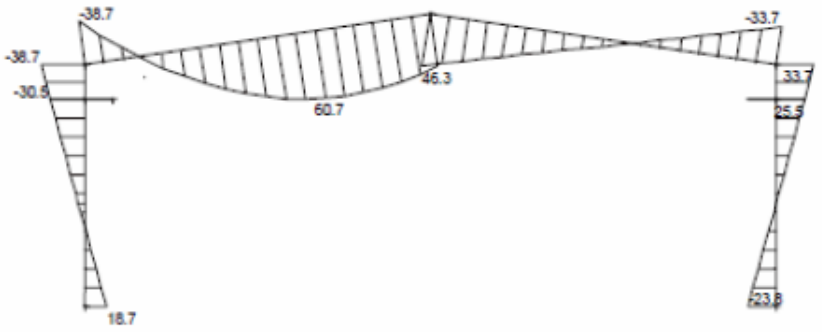
Snow load, case I



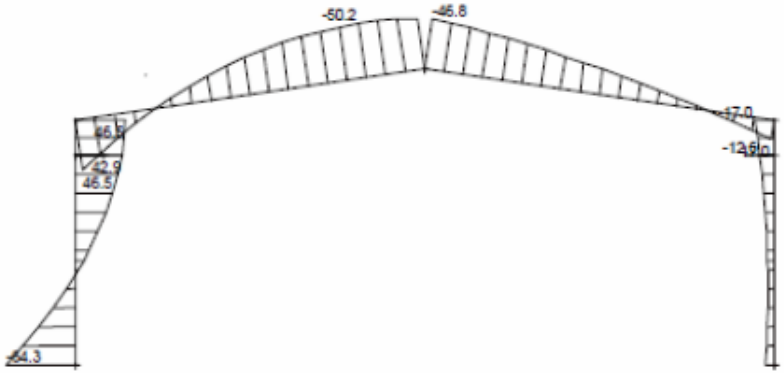
Internal forces due to actions (cont.-d)

Bending moments (cont'd):

Snow load, case II



Wind load



Combination of actions

Load cases overview

Loading	COLUMN				BEAM			
	Start point		End point		Start point		End point	
	N [kN]	M [kNm]	N [kN]	M [kNm]	N [kN]	M [kNm]	N [kN]	M [kNm]
self weight	-27,8	17,0	-17,0	-29,0	-8,7	-29,0	-8,0	37,3
roof	-20,2	22,7	-20,2	-38,6	-20,2	-38,6	-8,0	49,8
crane	-179,1	68,7	-9,8	-99,3	-10,0	34,7	-10,0	10,0
snow I	-75,8	85,0	-75,8	-144,9	-43,7	-144,9	-30,0	186,6
snow II	-28,7	18,7	-28,7	-38,7	-12,4	-38,7	-9,5	46,3
wind	-10,5	-12,6	-10,5	-17,0	5,3	17,0	5,3	-46,8

Combination of actions (cont.-d)

Ultimate limit state, fundamental combinations:

The design value of the effects of actions E_d *is calculated from the combination of actions* according to the expression (6.10) of the EN 1990

$$E_d = E(\gamma_{G,j}\, G_{k,j} + \gamma_{Q,1}\, Q_{k,1} + \Sigma\, \gamma_{Q,i}\, \psi_{0,i}\, Q_{k,i})$$

Combination I, leading action R: $1{,}35 \cdot G + 1{,}5 \cdot (R + 0{,}7 \cdot C + 0{,}5 \cdot S + 0{,}6 \cdot W)$
Combination II, leading action C: $1{,}35 \cdot G + 1{,}5 \cdot (C + 0{,}0 \cdot R + 0{,}5 \cdot S + 0{,}6 \cdot W)$
Combination III, leading action S: $1{,}35 \cdot G + 1{,}5 \cdot (S + 0{,}0 \cdot R + 0{,}7 \cdot C + 0{,}6 \cdot W)$
Combination IV, leading action W: $1{,}35 \cdot G + 1{,}5 \cdot (W + 0{,}0 \cdot R + 0{,}7 \cdot C + 0{,}5 \cdot S)$

where: G - self weight; R - imposed load on roofs; C - crane load;
S - snow load, case I; W – wind load.

Combination of actions (cont.-d)

$$E_d = E\left\{\gamma_{G,j} G_{k,j} ; \gamma_P P ; \gamma_{Q,1} Q_{k,1} ; \gamma_{Q,i} \psi_{0,i} Q_{k,i}\right\} \quad j \geq 1 ; i > 1$$

$$\leq \quad R_d = \frac{1}{\gamma_{Rd}} R\left\{X_{d,i}; a_d\right\} = \frac{1}{\gamma_{Rd}} R\left\{\eta_i \frac{X_{k,i}}{\gamma_{m,i}}; a_d\right\} \quad i \geq 1$$