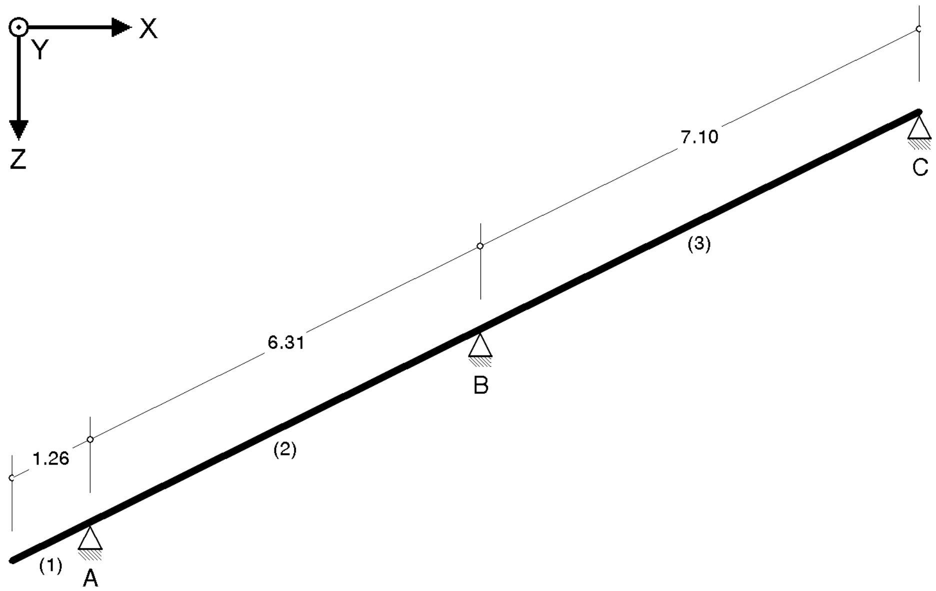
POSITION 3: HIP RAFTER

system: hip rafter



system parameters

overall length:	14.68 m
angle of slope:	26.34°
material:	coniferous timber: C24 with E = 11000 N/mm²
cross-section:	b=12.0 cm, h=28.0 cm
design codes:	Eurocode: EN 1990 (load factors), EN 1991 (wind and snow loads), EN 1995 (timber constr.)
nat. annex:	NA-DE (Deutschland)

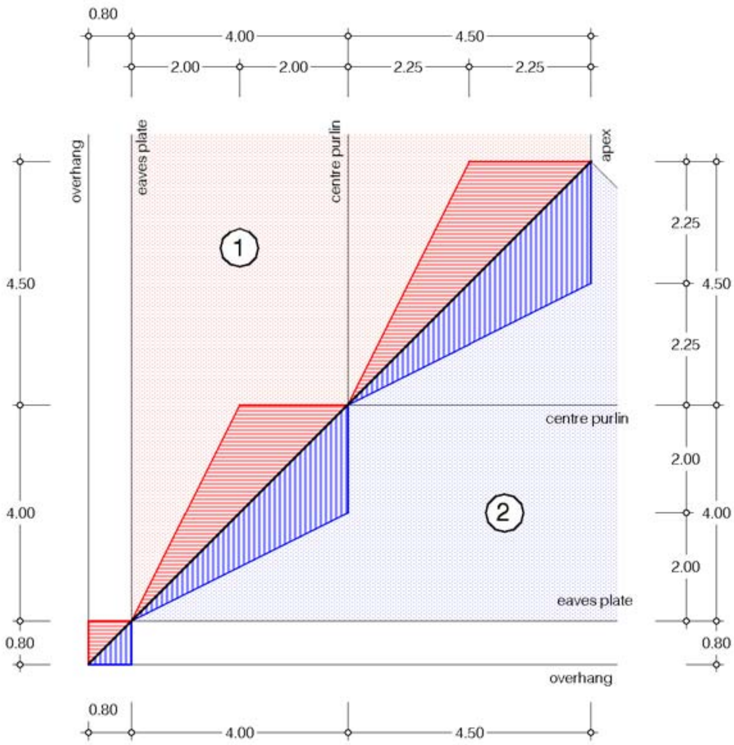
support, hinges, notches

ξ runs in bar direction from bottom to top beam end.
column c indicates the notch depth perpendicular to the bar centre-line.

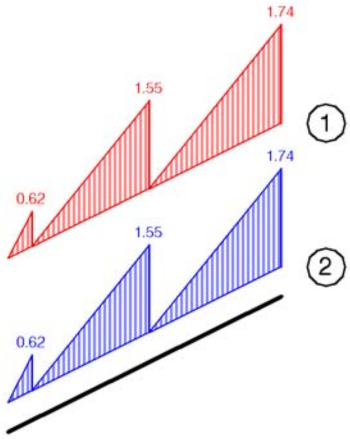
node	at ξ	support direction X	Y	Z	hinge	c
-	m	-	-	-	-	cm
A	1.26	fix	fix	fix	-	0.0
B	7.57	fix	fix	fix	-	0.0
C	14.68	fix	fix	fix	-	0.0

load weighting factors

the distributed loads assigned to the adjacent roof areas - multiplied with the load weighting factors - are placed as line loads on the rafter.



proj.	factor	value
0.80	0.77	0.62
2.00	0.77	1.55
2.25	0.77	1.74
0.80	0.77	0.62
2.00	0.77	1.55
2.25	0.77	1.74



load weighting factors

loading structure

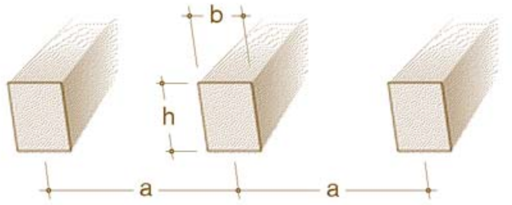
On the left-hand side, the relationship between the actions effects and load cases are shown in a tree structure. The right-hand side shows the characteristics of the superposition to the associated objects on the left-hand.

used symbols: action effect load case

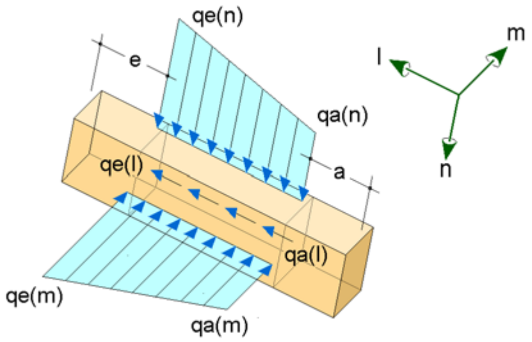
permanent loads	**permanent**
1: dead load	additive (dead load of supporting structure)
2: outer skin	additive (dead load of outer skin)
3: interior finish work	additive (dead load of interior finish work)
man loads	**category H: roofs**
4: man load(1)	alternative (on protruding roof (bottom, left side))
5: man load(2)	alternative (midspan (span 1))
6: man load(3)	alternative (midspan (span 2))
wind loads	**wind loads**
7: wind from left side	alternative
8: wind from right side	alternative
9: wind from front	alternative
snow loads	**snow loads (locations up to NN+1000m)**
10: snow fully	alternative

load case 1: dead load
dead load of supporting structure

hip rafter:	densitiy γ = 5.00 kN/m³	⇒ unif.distr. l.load:	0.28 * 0.12 * 5.00 =	**0.17 kN/m**
jack rafter:	densitiy γ = 5.00 kN/m³	⇒ distributed load:	0.20 * 0.14 * 5.00 / 0.80 =	**0.17 kN/m²**



h = 20.00 cm
b = 14.00 cm
a = 0.80 m



direction:	
vertical	vertical from top to bottom
wind1	perpendicular to roof area 1)[1]
wind2	perpendicular to roof area 2)[1]

)[1] positive = pressure

section partitioning see system sketch

trapezoidal loads (sectionally) of load case 1: dead load

section -	direct. -	a m	qa kN/m	qa(l) kN/m	qa(m) kN/m	qa(n) kN/m	e m	qe kN/m	qe(l) kN/m	qe(m) kN/m	qe(n) kN/m	from
1	**vertical**	0.00	**0.168**	-0.075	0.000	0.151	0.00	**0.168**	-0.075	0.000	0.151	dead load
1	**vertical**	0.00	**0.000**	0.000	0.000	0.000	0.00	**0.108**	-0.048	0.000	0.097	roof area 1
1	**vertical**	0.00	**0.000**	0.000	0.000	0.000	0.00	**0.108**	-0.048	0.000	0.097	roof area 2
2	**vertical**	0.00	**0.168**	-0.075	0.000	0.151	0.00	**0.168**	-0.075	0.000	0.151	dead load
2	**vertical**	0.00	**0.000**	0.000	0.000	0.000	0.00	**0.271**	-0.120	0.000	0.243	roof area 1
2	**vertical**	0.00	**0.000**	0.000	0.000	0.000	0.00	**0.271**	-0.120	0.000	0.243	roof area 2
3	**vertical**	0.00	**0.168**	-0.075	0.000	0.151	0.00	**0.168**	-0.075	0.000	0.151	dead load
3	**vertical**	0.00	**0.000**	0.000	0.000	0.000	0.00	**0.305**	-0.135	0.000	0.273	roof area 1
3	**vertical**	0.00	**0.000**	0.000	0.000	0.000	0.00	**0.305**	-0.135	0.000	0.273	roof area 2

load case 2: outer skin
dead load of outer skin

description	value
interlocking clay tile acc. to DIN 456 incl. lathing	0.550 kN/m²
vapour barrier made of plastic sheeting	0.020 kN/m²
6 cm fiber insulating material acc. to DIN 18 165	0.060 kN/m²
load sum :	**0.630 kN/m²**

trapezoidal loads (sectionally) of load case 2: outer skin

section -	direct. -	a m	qa kN/m	qa(l) kN/m	qa(m) kN/m	qa(n) kN/m	e m	qe kN/m	qe(l) kN/m	qe(m) kN/m	qe(n) kN/m	from
1	**vertical**	0.00	**0.000**	0.000	0.000	0.000	0.00	**0.390**	-0.173	0.000	0.349	roof area 1
1	**vertical**	0.00	**0.000**	0.000	0.000	0.000	0.00	**0.390**	-0.173	0.000	0.349	roof area 2
2	**vertical**	0.00	**0.000**	0.000	0.000	0.000	0.00	**0.975**	-0.432	0.000	0.874	roof area 1
2	**vertical**	0.00	**0.000**	0.000	0.000	0.000	0.00	**0.975**	-0.432	0.000	0.874	roof area 2
3	**vertical**	0.00	**0.000**	0.000	0.000	0.000	0.00	**1.097**	-0.487	0.000	0.983	roof area 1
3	**vertical**	0.00	**0.000**	0.000	0.000	0.000	0.00	**1.097**	-0.487	0.000	0.983	roof area 2

load case 3: interior finish work
dead load of interior finish work

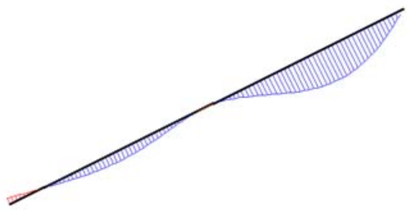
description	value
3/5 lathing	0.030 kN/m²
1,3 cm particle board DIN 68 763	0.100 kN/m²
load sum :	**0.130 kN/m²**

trapezoidal loads (sectionally) of load case 3: interior finish work

section	direct.	a	qa	qa(l)	qa(m)	qa(n)	e	qe	qe(l)	qe(m)	qe(n)	from
-	-	m	kN/m	kN/m	kN/m	kN/m	m	kN/m	kN/m	kN/m	kN/m	
1	**vertical**	0.00	**0.000**	0.000	0.000	0.000	0.00	**0.080**	-0.036	0.000	0.072	roof area 1
1	**vertical**	0.00	**0.000**	0.000	0.000	0.000	0.00	**0.080**	-0.036	0.000	0.072	roof area 2
2	**vertical**	0.00	**0.000**	0.000	0.000	0.000	0.00	**0.201**	-0.089	0.000	0.180	roof area 1
2	**vertical**	0.00	**0.000**	0.000	0.000	0.000	0.00	**0.201**	-0.089	0.000	0.180	roof area 2
3	**vertical**	0.00	**0.000**	0.000	0.000	0.000	0.00	**0.226**	-0.100	0.000	0.203	roof area 1
3	**vertical**	0.00	**0.000**	0.000	0.000	0.000	0.00	**0.226**	-0.100	0.000	0.203	roof area 2

extremal deflections

deformations perpendicular to the member centre-line
sum of all permanent loads



(max w = 11.4 mm. min w = -2.3 mm)

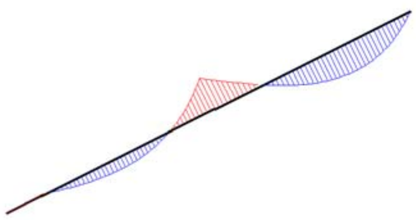
extremal support reactions

sum of all permanent loads in kN

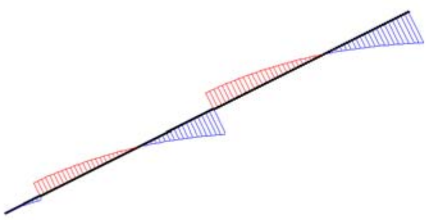
supp.	H	V
A	-0.57	3.36
B	1.11	13.30
C	-0.53	7.22

extremal internal forces

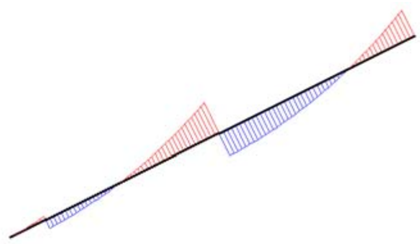
sum of all permanent loads



max Mm = 7.07 kNm, min Mm = -8.55 kNm



max N = 3.68 kN, min N = -1.97 kN

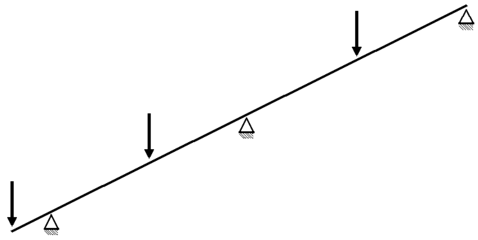


max Vn = 5.19 kN, min Vn = -7.22 kN

action effect of man loads

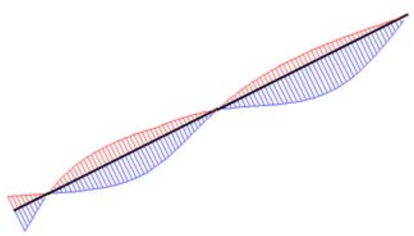
man loads are placed in each midspan
resp. at the cantilevers end. load value: P = 1.00 kN.
the following alternative load cases are analysed.

LF	description	explanation
4	man load(1)	on protruding roof (bottom, left side)
5	man load(2)	midspan (span 1)
6	man load(3)	midspan (span 2)



extremal deflections

deformations perpendicular to the member centre-line
Extremal from all load cases of the action effect man loads



(max w = 2.0 mm. min w = -0.9 mm)

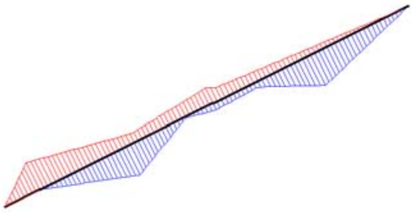
extremal support reactions

Extremal from all load cases of the action effect man loads in kN

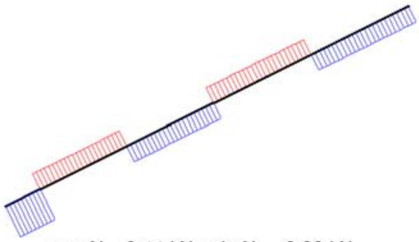
supp.	H		V	
	min	max	min	max
A	-0.04	0.10	-0.09	1.20
B	-0.11	0.08	-0.23	0.67
C	-0.04	0.02	-0.06	0.42

extremal internal forces

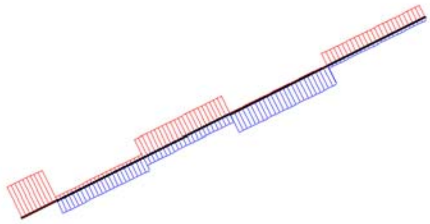
Extremal from all load cases of the action effect man loads



max Mm = 1.28 kNm, min Mm = -1.13 kNm



max N = 0.44 kN, min N = -0.22 kN

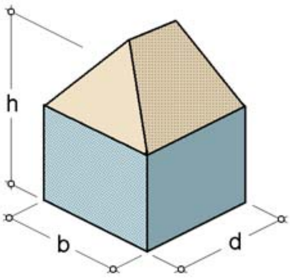


max Vn = 0.54 kN, min Vn = -0.90 kN

action effect of wind loads

ground roughness profile acc. to DIN 1055-4 resp. DIN EN 1991-1-4/NA: inland

wind zone:	2
h + NN:	60 m
factor:	1.0000
qref:	0.39 kN/m²
h:	10.25 m
b:	8.50 m
d:	12.00 m
⇒ q(h):	**0.67 kN/m²**



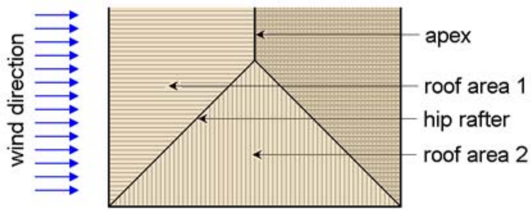
the following alternative load cases are analysed.

LF	description	explanation
7	wind from left side	
8	wind from right side	
9	wind from front	

load case 7: wind from left side

external pressure coefficients $c_{pe,10}$ in the area of the hip rafter
acc. to DIN 1055-4:2005-03 Tab. 7 resp. EN 1991-1-4 Tab. 7.5
(+) = pressure (-) = suction tab. input value: $\alpha_0 = 35°$

roof area	zone	$c_{pe,10}$	$q = c_{pe,10} * q(h)$
1	F	0.57	0.38 kN/m²
2	L	-1.37	-0.91 kN/m²



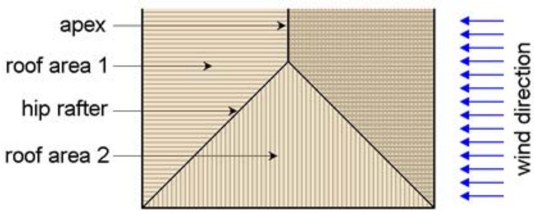
trapezoidal loads (sectionally) of load case 7: wind from left side

section	direct.	a	qa	qa(l)	qa(m)	qa(n)	e	qe	qe(l)	qe(m)	qe(n)	from
-	-	m	kN/m	kN/m	kN/m	kN/m	m	kN/m	kN/m	kN/m	kN/m	
1	**Wind1**	0.00	**0.000**	0.000	0.000	0.000	0.00	**0.235**	0.000	0.095	0.214	roof area 1
1	**Wind2**	0.00	**0.000**	0.000	0.000	0.000	0.00	**-0.566**	0.000	0.230	-0.517	roof area 2
2	**Wind1**	0.00	**0.000**	0.000	0.000	0.000	0.00	**0.587**	0.000	0.238	0.536	roof area 1
2	**Wind2**	0.00	**0.000**	0.000	0.000	0.000	0.00	**-1.415**	0.000	0.574	-1.293	roof area 2
3	**Wind1**	0.00	**0.000**	0.000	0.000	0.000	0.00	**0.660**	0.000	0.268	0.603	roof area 1
3	**Wind2**	0.00	**0.000**	0.000	0.000	0.000	0.00	**-1.592**	0.000	0.646	-1.455	roof area 2

load case 8: wind from right side

external pressure coefficients $c_{pe,10}$ in the area of the hip rafter
acc. to DIN 1055-4:2005-03 Tab. 7 resp. EN 1991-1-4 Tab. 7.5
(+) = pressure (-) = suction tab. input value: $\alpha_0 = 35°$

roof area	zone	$c_{pe,10}$	$q = c_{pe,10} * q(h)$
1	J	-0.67	-0.45 kN/m²
2	M	-0.80	-0.54 kN/m²



trapezoidal loads (sectionally) of load case 8: wind from right side

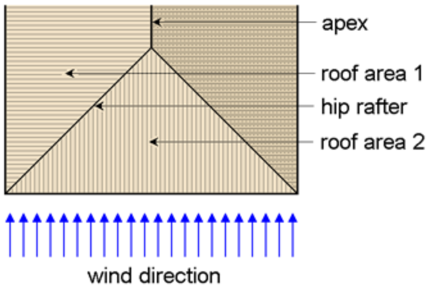
section -	direct. -	a m	qa kN/m	qa(l) kN/m	qa(m) kN/m	qa(n) kN/m	e m	qe kN/m	qe(l) kN/m	qe(m) kN/m	qe(n) kN/m	from
1	**Wind1**	0.00	**0.000**	0.000	0.000	0.000	0.00	**-0.276**	0.000	-0.112	-0.252	roof area 1
1	**Wind2**	0.00	**0.000**	0.000	0.000	0.000	0.00	**-0.331**	0.000	0.134	-0.303	roof area 2
2	**Wind1**	0.00	**0.000**	0.000	0.000	0.000	0.00	**-0.690**	0.000	-0.280	-0.631	roof area 1
2	**Wind2**	0.00	**0.000**	0.000	0.000	0.000	0.00	**-0.828**	0.000	0.336	-0.757	roof area 2
3	**Wind1**	0.00	**0.000**	0.000	0.000	0.000	0.00	**-0.776**	0.000	-0.315	-0.710	roof area 1
3	**Wind2**	0.00	**0.000**	0.000	0.000	0.000	0.00	**-0.932**	0.000	0.378	-0.852	roof area 2

load case 9: wind from front

external pressure coefficients $c_{pe,10}$ in the area of the hip rafter acc. to DIN 1055-4:2005-03 Tab. 7 resp. EN 1991-1-4 Tab. 7.5

(+) = pressure (-) = suction tab. input value: α_{90} = 35°

roof area	zone	$c_{pe,10}$	$q = c_{pe,10} * q(h)$
1	L	-1.37	-0.91 kN/m²
2	F	0.57	0.38 kN/m²

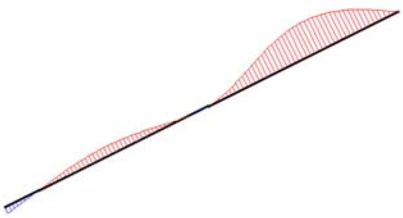


trapezoidal loads (sectionally) of load case 9: wind from front

section -	direct. -	a m	qa kN/m	qa(l) kN/m	qa(m) kN/m	qa(n) kN/m	e m	qe kN/m	qe(l) kN/m	qe(m) kN/m	qe(n) kN/m	from
1	**Wind1**	0.00	**0.000**	0.000	0.000	0.000	0.00	**-0.566**	0.000	-0.230	-0.517	roof area 1
1	**Wind2**	0.00	**0.000**	0.000	0.000	0.000	0.00	**0.235**	0.000	-0.095	0.214	roof area 2
2	**Wind1**	0.00	**0.000**	0.000	0.000	0.000	0.00	**-1.415**	0.000	-0.574	-1.293	roof area 1
2	**Wind2**	0.00	**0.000**	0.000	0.000	0.000	0.00	**0.587**	0.000	-0.238	0.536	roof area 2
3	**Wind1**	0.00	**0.000**	0.000	0.000	0.000	0.00	**-1.592**	0.000	-0.646	-1.455	roof area 1
3	**Wind2**	0.00	**0.000**	0.000	0.000	0.000	0.00	**0.660**	0.000	-0.268	0.603	roof area 2

extremal deflections

deformations perpendicular to the member centre-line
Extremal from all load cases of the action effect wind loads



(max w = 1.1 mm, min w = -5.6 mm)

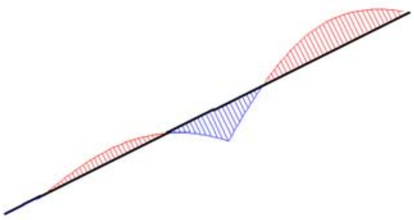
extremal support reactions

Extremal from all load cases of the action effect wind loads in kN

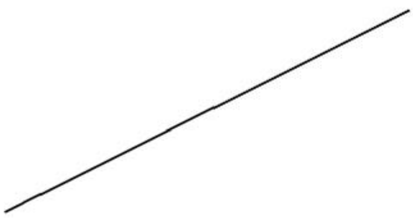
support	Hx min	 max	V min	 max	Hy min	 max
A	-0.52	0.00	-1.06	0.00	-0.69	0.69
B	-2.65	0.00	-5.36	0.00	-3.50	3.50
C	-1.38	0.00	-2.79	0.00	-1.82	1.82

extremal internal forces

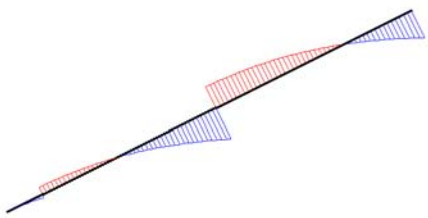
Extremal from vertical load components from all load cases of action effect wind loads



max Mm = 4.13 kNm, min Mm = -3.48 kNm



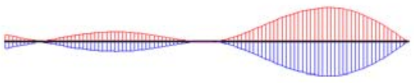
max N = 0.00 kN, min N = 0.00 kN



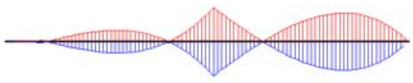
max Vn = 3.55 kN, min Vn = -2.43 kN

extremal internal forces

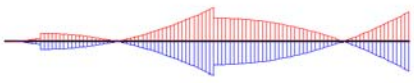
Extremal from horizontal load components from load cases of action effect



(max w = 17.7 mm, min w = -17.7 mm)



max Mn = 2.42 kNm, min Mn = -2.42 kNm



max Vm = 2.08 kN, min Vm = -2.08 kN

action effect of snow loads

snow load zone:	1
h + NN:	60 m
⇒ s_k:	0.65 kN/m²

the following load case is analysed.

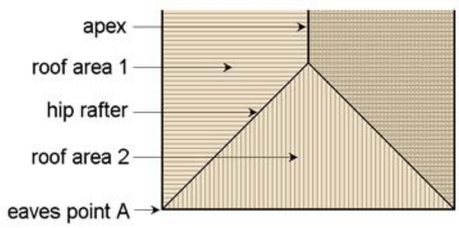
LF	description
10	snow fully

load case 10: snow fully

load determination acc. to EN 1991-1-3

If snow sliding is prevented by snowguards or the like the shape coefficient μ_1 is specified to 0.8 regardless of the roof pitch.

roof area	pitch	μ_1	$q = \mu_1\ s_k \cos\alpha$
1	35	0.67	0.35 kN/m²
2	35	0.80	0.43 kN/m²

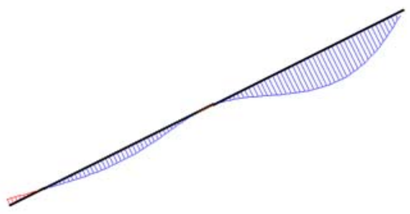


trapezoidal loads (sectionally) of load case 10: snow fully

section	direct.	a	qa	qa(l)	qa(m)	qa(n)	e	qe	qe(l)	qe(m)	qe(n)	from
-	-	m	kN/m	kN/m	kN/m	kN/m	m	kN/m	kN/m	kN/m	kN/m	
1	**vertical**	0.00	**0.000**	0.000	0.000	0.000	0.00	**0.220**	-0.097	0.000	0.197	roof area 1
1	**vertical**	0.00	**0.000**	0.000	0.000	0.000	0.00	**0.264**	-0.117	0.000	0.236	roof area 2
2	**vertical**	0.00	**0.000**	0.000	0.000	0.000	0.00	**0.549**	-0.244	0.000	0.492	roof area 1
2	**vertical**	0.00	**0.000**	0.000	0.000	0.000	0.00	**0.659**	-0.292	0.000	0.591	roof area 2
3	**vertical**	0.00	**0.000**	0.000	0.000	0.000	0.00	**0.618**	-0.274	0.000	0.554	roof area 1
3	**vertical**	0.00	**0.000**	0.000	0.000	0.000	0.00	**0.741**	-0.329	0.000	0.664	roof area 2

extremal deflections

deformations perpendicular to the member centre-line
Extremal from all load cases of the action effect snow loads



(max w = 4.3 mm, min w = -0.9 mm)

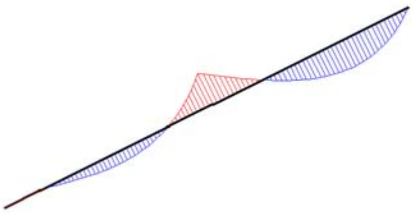
extremal support reactions

Extremal from all load cases of the action effect snow loads in kN

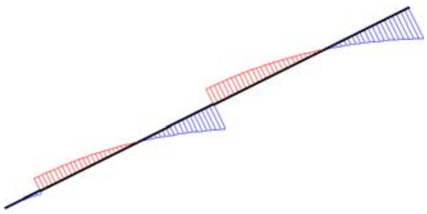
supp.	H		V	
	min	max	min	max
A	-0.22	0.00	0.00	1.13
B	0.00	0.42	0.00	5.00
C	-0.20	0.00	0.00	2.81

extremal internal forces

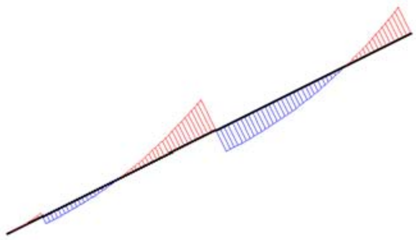
Extremal from all load cases of the action effect snow loads



max Mm = 2.72 kNm, min Mm = -3.22 kNm



max N = 1.43 kN, min N = -0.71 kN



max Vn = 1.90 kN, min Vn = -2.77 kN

main verification

verification of load-carrying capacity for permanent and transient design situations

service class of building	1
material safety factor	1.30
combination of internal forces	acc.to EN 1990

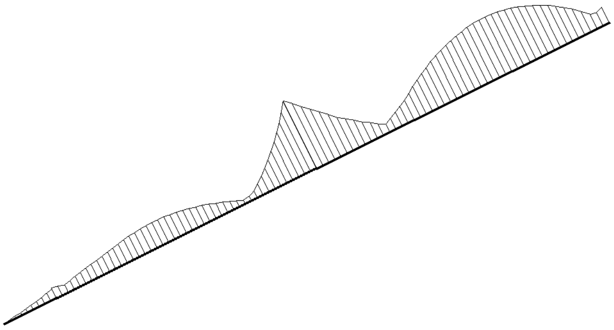
stability analysis is executed with the following instability factors and f. for lateral buckling

section	buckling (vertical) lef	buckling (vertical) kc,y	buckling (horizontal) lef	buckling (horizontal) kc,z	overturning lef	overturning km
-	m	-	m	-	m	-
1	1.26	1.0000	1.26	0.9101	1.26	1.0000
2	6.31	0.4642	6.31	0.0975	6.31	1.0000
3	7.10	0.3808	7.10	0.0776	7.10	0.9916

safety and combination coefficients, classes of duration of load

action effect	γ_{sup}	γ_{inf}	Ψ_{dom}	Ψ_{sub}	KLED	k_{mod}
permanent loads	1.35	1.00	1.00	1.00	permanent	0.60
man loads	1.50	0.00	1.00	0.00	sh.-term	0.90
wind loads	1.50	0.00	1.00	0.60	sh.-v.sh.	1.00
snow loads	1.50	0.00	1.00	0.50	sh.-term	0.90

maximal degree of utilization
max U = 0.69



formal verification of maximal utilization

decisive point at ξ = 7.57 m (ξ runs from bottom left side to top right side)
decisive internal forces and moments: min N, zug My, zug Vz, zug Mz, zug Vy
decisive state of stress: normal stress
leading traffic effect: keine

action effect	γ	Ψ	factor	N_k	$M_{y,k}$	$V_{z,k}$	$M_{z,k}$	$V_{y,k}$	N_d	$M_{y,d}$	$V_{z,d}$	$M_{z,d}$	$V_{y,d}$
permanent loads	1.35	1.00	1.35	-1.97	-8.55	5.19	0.00	0.00	-2.66	-11.54	7.01	0.00	0.00
man loads	0.00	1.00	0.00	-0.22	-0.63	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00
wind loads	0.00	0.60	0.00	0.00	2.25	-1.33	2.42	-1.42	0.00	0.00	0.00	0.00	0.00
snow loads	0.00	0.50	0.00	-0.71	-3.22	1.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
sum (= design internal forces and moments in kN, kNm)									-2.66	-11.54	7.01	0.00	0.00

section properties: h = 28.0 cm, b = 12.0 cm

A = 0.0336000 m²
Wy = 0.0015680 m³
Wz = 0.0006720 m³

stresses:

$\sigma_{c,0,d} = N_d / A$ = 0.0010 * -2.66 / 0.033600 = -0.08 N/mm²
$\sigma_{m,y,d} = M_{y,d} / W_y$ = 0.0010 * -11.54 / 0.001568 = -7.36 N/mm²
$\sigma_{m,z,d} = M_{z,d} / W_z$ = 0.0010 * 0.00 / 0.000672 = 0.00 N/mm²
$\tau_{z,d} = 1.5\, V_{z,d} / A$ = 0.0015 * 7.01 / 0.033600 = 0.31 N/mm²
$\tau_{y,d} = 1.5\, V_{y,d} / A$ = 0.0015 * 0.00 / 0.033600 = 0.00 N/mm²

characteristic strengths acc. to Eurocode: $f_{c,0,k}$ = 21.00, $f_{m,k}$ = 24.00 N/mm²
design values with γ_M = 1.30 und k_{mod} = 0.60: $f_{c,0,d}$ = 9.69, $f_{m,d}$ = 11.08 N/mm² (k_{red} = 0.7)

$$\text{max utilization } U = \frac{|\sigma_{c,0,d}|}{k_{c,y}\ f_{c,0,d}} + \frac{|\sigma_{m,y,d}|}{k_m\ f_{m,d}} + k_{red}\frac{|\sigma_{m,z,d}|}{f_{m,d}} = \frac{0.08}{0.3808\ 9.69} + \frac{7.36}{0.9916\ 11.08} + 0.7\ \frac{0.00}{11.08} = \underline{\underline{0.69 \leq 1.00}}$$

special verification "Norddeutsche Tiefebene"

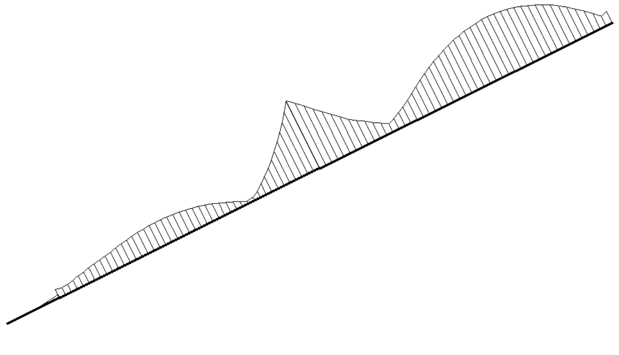
verification of load-carrying capacity for accidental design situations

service class of building	1
material safety factor	1.00
combination of internal forces	acc. to DIN 1055-100

safety and combination coefficients, classes of duration of load

action effect	γ_{sup}	γ_{inf}	Ψ_{dom}	Ψ_{sub}	KLED	k_{mod}
permanent loads	1.00	1.00	1.00	1.00	permanent	0.60
man loads	1.00	0.00	0.00	0.00	sh.-term	0.90
wind loads	1.00	0.00	0.20	0.00	1.00	
snow loads	2.30	2.30	1.00	1.00	sh.-term	0.90

maximal degree of utilization
max U = 0.49



formal verification of maximal utilization

decisive point at ξ = 7.57 m (ξ runs from bottom left side to top right side)
decisive internal forces and moments: min N, zug My, zug Vz, zug Mz, zug Vy
decisive state of stress: normal stress
leading traffic effect: man loads

action effect	γ	Ψ	factor	N_k	$M_{y,k}$	$V_{z,k}$	$M_{z,k}$	$V_{y,k}$	N_d	$M_{y,d}$	$V_{z,d}$	$M_{z,d}$	$V_{y,d}$
permanent loads	1.00	1.00	1.00	-1.97	-8.55	5.19	0.00	0.00	-1.97	-8.55	5.19	0.00	0.00
man loads	0.00	0.00	0.00	-0.22	-0.63	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00
wind loads	0.00	0.00	0.00	0.00	2.25	-1.33	2.42	-1.42	0.00	0.00	0.00	0.00	0.00
snow loads	2.30	1.00	2.30	-0.71	-3.22	1.90	0.00	0.00	-1.64	-7.41	4.36	0.00	0.00
sum (= design internal forces and moments in kN, kNm)									-3.62	-15.96	9.55	0.00	0.00

section properties: h = 28.0 cm, b = 12.0 cm

A = 0.0336000 m²
Wy = 0.0015680 m³
Wz = 0.0006720 m³

stresses:

$\sigma_{c,0,d} = N_d / A$ = 0.0010 * -3.62 / 0.033600 = -0.11 N/mm²
$\sigma_{m,y,d} = M_{y,d} / W_y$ = 0.0010 * -15.96 / 0.001568 = -10.18 N/mm²
$\sigma_{m,z,d} = M_{z,d} / W_z$ = 0.0010 * 0.00 / 0.000672 = 0.00 N/mm²
$\tau_{z,d} = 1.5\, V_{z,d} / A$ = 0.0015 * 9.55 / 0.033600 = 0.43 N/mm²
$\tau_{y,d} = 1.5\, V_{y,d} / A$ = 0.0015 * 0.00 / 0.033600 = 0.00 N/mm²

characteristic strengths acc. to Eurocode: $f_{c,0,k}$ = 21.00, $f_{m,k}$ = 24.00 N/mm²
design values with γ_M = 1.00 und k_{mod} = 0.90: $f_{c,0,d}$ = 18.90, $f_{m,d}$ = 21.60 N/mm² (k_{red} = 0.7)

$$\text{max utilization } U = \frac{|\sigma_{c,0,d}|}{k_{c,y}\ f_{c,0,d}} + \frac{|\sigma_{m,y,d}|}{k_m\ f_{m,d}} + k_{red}\frac{|\sigma_{m,z,d}|}{f_{m,d}} = \frac{0.11}{0.3808\ 18.90} + \frac{10.18}{0.9916\ 21.60} + 0.7\,\frac{0.00}{21.60} = \underline{\underline{0.49 \le 1.00}}$$

verification of fire protection

fire load	four-sided
required fire resistance period	30 minutes
combustion depth	2.40 cm
verification method	reduced properties method (EN 1995-1-2))
material safety factor	1.00
combination of internal forces	acc.to EN 1990

reduced cross-sections and strength values

h_r	b_r	u_r	A_r	$f_{m,d}$	$f_{c0,d}$	$f_{t,d}$
cm	cm	cm	cm²	N/mm²	N/mm²	N/mm²
23.20	7.20	60.80	167.04	24.54	18.61	15.57

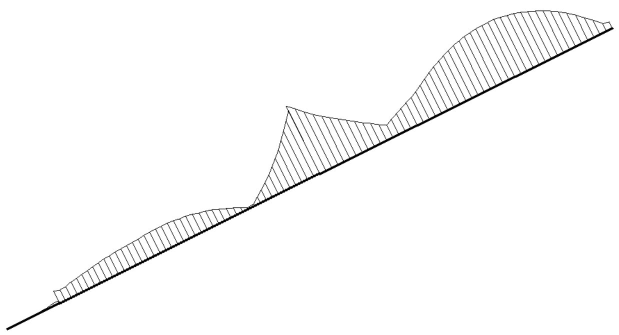
reduced instability factors and f. for lateral buckling

section	buckling (vertical) lef	kc,y	buckling (horizontal) lef	kc,z	overturning lef	km
-	m	-	m	-	m	-
1	1.26	1.0000	1.26	0.7455	1.26	1.0000
2	6.31	0.4106	6.31	0.0450	6.31	0.7713
3	7.10	0.3344	7.10	0.0358	7.10	0.7235

partial safety factors and combination coefficients

action effect	γ_{sup}	γ_{inf}	Ψ_{dom}	Ψ_{sub}
permanent loads	1.00	1.00	1.00	1.00
man loads	1.00	0.00	0.00	0.00
wind loads	1.00	0.00	0.00	0.00
snow loads	1.00	0.00	0.00	0.00

maximal degree of utilization
max U = 0.76



formal verification of maximal utilization

decisive point at ξ = 7.57 m (ξ runs from bottom left side to top right side)
decisive internal forces and moments: max N, zug My, zug Vz, zug Mz, zug Vy
decisive state of stress: normal stress
leading traffic effect: keine

action effect	γ	Ψ	factor	N_k	$M_{y,k}$	$V_{z,k}$	$M_{z,k}$	$V_{y,k}$	N_d	$M_{y,d}$	$V_{z,d}$	$M_{z,d}$	$V_{y,d}$
permanent loads	1.00	1.00	1.00	-1.97	-8.55	5.19	0.00	0.00	-1.97	-8.55	5.19	0.00	0.00
man loads	0.00	0.00	0.00	0.00	-0.50	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00
wind loads	0.00	0.00	0.00	0.00	2.25	-1.33	2.42	-1.42	0.00	0.00	0.00	0.00	0.00
snow loads	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
sum (= design internal forces and moments in kN, kNm)									-1.97	-8.55	5.19	0.00	0.00

section properties: h = 23.2 cm, b = 7.2 cm

A = 0.0167040 m²
Wy = 0.0006459 m³
Wz = 0.0002004 m³

stresses:

$\sigma_{c,0,d} = N_d / A = 0.0010 * -1.97 / 0.016704 = -0.12$ N/mm²
$\sigma_{m,y,d} = M_{y,d} / W_y = 0.0010 * -8.55 / 0.000646 = -13.23$ N/mm²
$\sigma_{m,z,d} = M_{z,d} / W_z = 0.0010 * 0.00 / 0.000200 = 0.00$ N/mm²
$\tau_{z,d} = 1.5 V_{z,d} / A = 0.0015 * 5.19 / 0.016704 = 0.47$ N/mm²
$\tau_{y,d} = 1.5 V_{y,d} / A = 0.0015 * 0.00 / 0.016704 = 0.00$ N/mm²

$$\text{max utilization } U = \frac{|\sigma_{c,0,d}|}{k_{c,y}\ f_{c,0,d}} + \frac{|\sigma_{m,y,d}|}{k_m\ f_{m,d}} + k_{red}\frac{|\sigma_{m,z,d}|}{f_{m,d}} = \frac{0.12}{0.3344\ 18.61} + \frac{13.23}{0.7235\ 24.54} + 0.7\frac{0.00}{24.54} = \underline{\underline{0.76 \leq 1.00}}$$

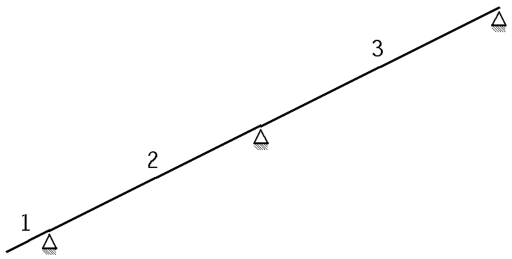
verifications of serviceability limit states

comparative lengths

for calculation of degree of utilization

section	true length	l_v vert.	l_v hor.
-	m	m	m
1	1.26	1.26	1.26
2	6.31	6.31	6.31
3	7.10	7.10	7.10

sections



limit values

deformation	in span	at cantilever
w_{inst}	$l_v/300$	$l_v/150$
w_{fin}	$l_v/200$	$l_v/100$

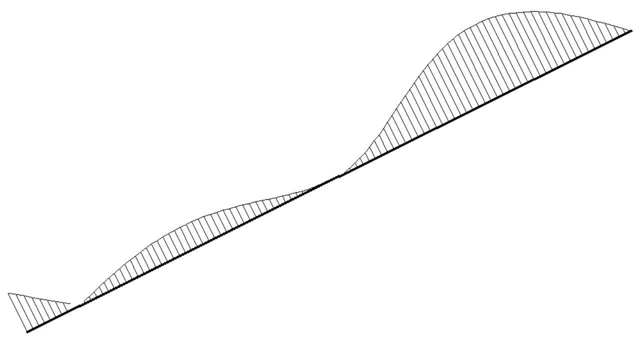
verification of serviceability limit state w_{inst}

combination coefficients

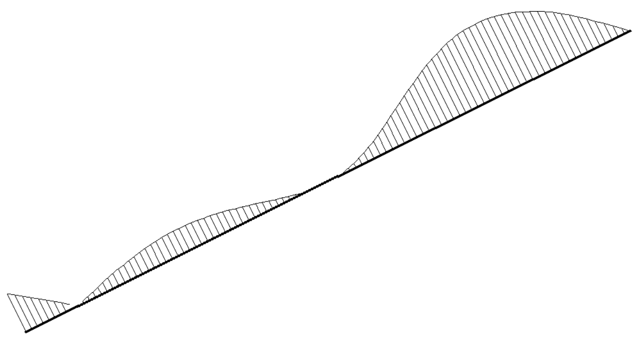
action effect	Ψ_0
man loads	0.00
wind loads	0.60
snow loads	0.50

service class 1
⇒ k_{def} = 0.60

maximal degree of utilization
from vertical load components
max U = 0.66



maximal degree of utilization
from horizontal load components
max U = 0.75



formal verification of maximal utilization from vertical load components

decisive point at ξ = 11.72 m (ξ runs from bottom left side to top right side)
leading traffic effect: snow loads
decisive deformation: max w
decisive comparative length: 7.10 m (alle deflections in mm)

action effect	γ	Ψ	F	w_k	w_{inst}
permanent loads	1.00	1.00	1.00	11.39	11.39
man loads	0.00	0.00	0.00	1.90	0.00
wind loads	0.00	0.60	0.00	0.00	0.00
snow loads	1.00	1.00	1.00	4.34	4.34
sum (in mm)					15.72

decisive max utilization U = $\frac{w_{inst}}{l_v / 300}$ = 0.66 ≤ 1.00

formal verification of maximal utilization from horizontal load components

decisive point at ξ = 11.72 m (ξ runs from bottom left side to top right side)
leading traffic effect: wind loads
decisive deformation: max w
decisive comparative length: 7.10 m (alle deflections in mm)

action effect	γ	Ψ	F	w_k	w_{inst}
permanent loads	1.00	1.00	1.00	0.00	0.00
man loads	0.00	0.00	0.00	0.00	0.00
wind loads	1.00	1.00	1.00	17.70	17.70
snow loads	0.00	0.50	0.00	0.00	0.00
sum (in mm)					17.70

decisive max utilization U = $\frac{w_{inst}}{l_v / 300}$ = 0.75 ≤ 1.00

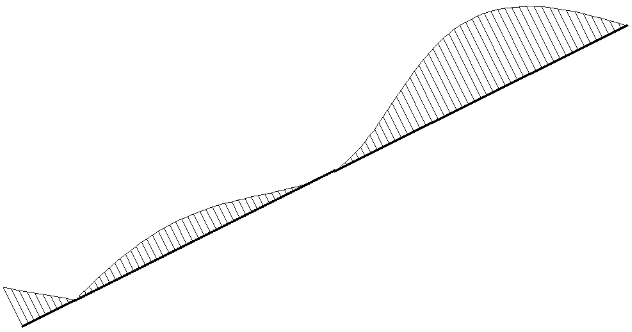
verification of serviceability limit state w_{fin}

combination coefficients

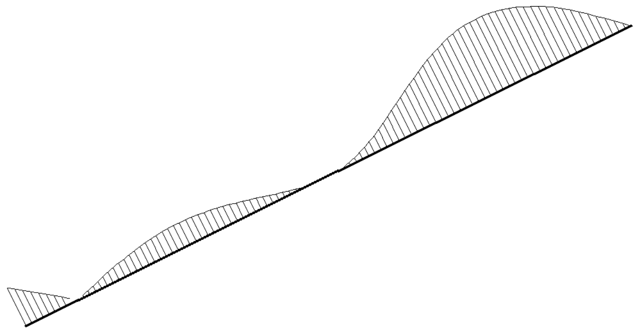
action effect	Ψ_0	Ψ_2
man loads	0.00	0.00
wind loads	0.60	0.00
snow loads	0.50	0.00

service class 1
⇒ k_{def} = 0.60

maximal degree of utilization
from vertical load components
max U = 0.64



maximal degree of utilization
from horizontal load components
max U = 0.50



formal verification of maximal utilization from vertical load components

decisive point at ξ = 11.72 m (ξ runs from bottom left side to top right side)
leading traffic effect: snow loads
decisive deformation: max w
decisive comparative length: 7.10 m (alle deflections in mm)

action effect	γ	Ψ	$\Psi_2 k_{def}$	F	w_k	w_{fin}
permanent loads	1.00	1.00	0.60	1.60	11.39	18.22
man loads	0.00	0.00	0.00	0.00	1.90	0.00
wind loads	0.00	0.60	0.00	0.00	0.00	0.00
snow loads	1.00	1.00	0.00	1.00	4.34	4.34
sum (in mm)						22.56

decisive max utilization U = $\frac{w_{inst}}{l_v / 200}$ = 0.64 ≤ 1.00

formal verification of maximal utilization from horizontal load components

decisive point at ξ = 11.72 m (ξ runs from bottom left side to top right side)
leading traffic effect: wind loads
decisive deformation: max w
decisive comparative length: 7.10 m (alle deflections in mm)

action effect	γ	Ψ	$\Psi_2 k_{def}$	F	w_k	w_{fin}
permanent loads	1.00	1.00	0.60	1.60	0.00	0.00
man loads	0.00	0.00	0.00	0.00	0.00	0.00
wind loads	1.00	1.00	0.00	1.00	17.70	17.70
snow loads	0.00	0.50	0.00	0.00	0.00	0.00
sum (in mm)						17.70

decisive max utilization U = $\frac{w_{inst}}{l_v / 200}$ = 0.50 ≤ 1.00

extremal support reactions
on characteristic load level

Positive vertical reaction forces (V) are acting from bottom to top. Positive horizontal reaction forces (Hx) are acting from right to left side. Man loads and snow loads are never acting at the same time. If the result of the analysed man loads is max Av < 1.0, it is set to max Av = 1.0. Hereby the case of man load directly on the support is considered.

	G	Q			G+Q			from
		Hx	V	Hy	Hx	V	Hy	
	kN	kN	kN	kN	kN	kN	kN	
support A								
min A_{Hx}	-0.57	-0.74	-1.06	0.05	-1.31	2.30	0.05	G+W+S
max A_{Hx}	-0.57	0.10	1.20	0.00	-0.47	4.56	0.00	G+M
min A_V	3.36	-0.57	-1.15	0.05	-1.14	2.21	0.05	G+M+W
max A_V	3.36	0.10	1.20	0.00	-0.47	4.56	0.00	G+M
min A_{Hy}	0.00	-0.29	-0.58	-0.69	-0.86	2.78	-0.69	G+W
max A_{Hy}	0.00	-0.29	-0.58	0.69	-0.86	2.78	0.69	G+W
support B								
min B_{Hx}	1.11	-2.77	-5.59	0.24	-1.66	7.71	0.24	G+M+W
max B_{Hx}	1.11	0.42	5.00	0.00	1.53	18.30	0.00	G+S
min B_V	13.30	-2.77	-5.59	0.24	-1.66	7.71	0.24	G+M+W
max B_V	13.30	0.42	5.00	0.00	1.53	18.30	0.00	G+S
min B_{Hy}	0.00	-1.45	-2.92	-3.50	-0.34	10.38	-3.50	G+W
max B_{Hy}	0.00	-1.45	-2.92	3.50	-0.34	10.38	3.50	G+W
support C								
min C_{Hx}	-0.53	-1.58	-2.79	0.13	-2.12	4.43	0.13	G+W+S
max C_{Hx}	-0.53	0.02	0.03	0.00	-0.52	7.26	0.00	G+M
min C_V	7.22	-1.41	-2.85	0.13	-1.95	4.37	0.13	G+M+W
max C_V	7.22	0.00	2.81	0.00	-0.53	10.03	0.00	G+S
min C_{Hy}	0.00	-0.75	-1.52	-1.82	-1.29	5.70	-1.82	G+W
max C_{Hy}	0.00	-0.75	-1.52	1.82	-1.29	5.70	1.82	G+W