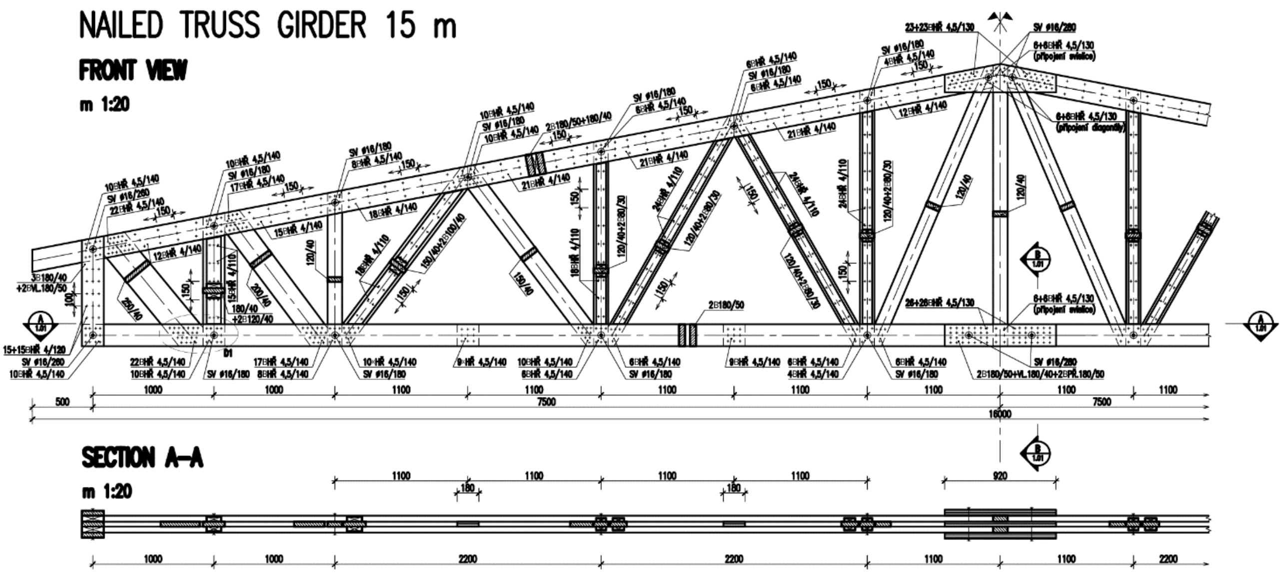
HOW TO CHECK CHORDS, DIAGONALS AND VERTICALS OF NAILED TRUSS GIRDER?

…worked examples for BO003 and BO006

WORKED EXAMPLE 3: NAILED TRUSS GIRDER

Make assessment of nailed timber truss girder members. Girder is made of solid timber C20. Members of truss girder is designed as solid and built-up using nails with diameter 4 mm without pre-drilling. Service class no 2 is considered.



Roof geometry

L = 15000 mm truss girder span

α = 12° pitch of the roof (slope)

Material

Solid timber C20 according to the EN 338

$E_{0,05}$ = 6,4 GPa 5% quantile value of modulus of elasticity parallel to the grain

$E_{0,\mathrm{mean}}$ = 9,5 GPa mean value of modulus of elasticity parallel to the grain

$f_{c,0,k}$ = 19 MPa characteristic compressive strength along the grain

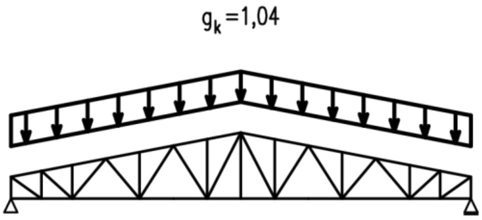
$f_{t,0,k}$ = 12 MPa characteristic tensile strength along the grain

$$f_{c,0,d} = k_{\mathrm{mod}} \cdot \frac{f_{c,0,k}}{\gamma_M} = 0{,}9 \cdot \frac{19}{1{,}3} = 13{,}15\ \mathrm{MPa}$$ design compressive strength along the grain

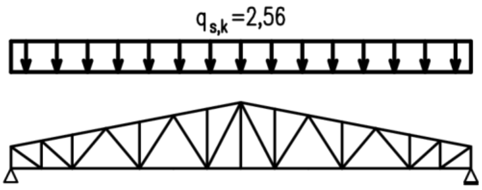
$$f_{t,0,d} = k_{\mathrm{mod}} \cdot \frac{f_{t,0,k}}{\gamma_M} = 0{,}9 \cdot \frac{12}{1{,}3} = 8{,}31\ \mathrm{MPa}$$ design tensile strength along the grain

Load states, combinations and internal forces

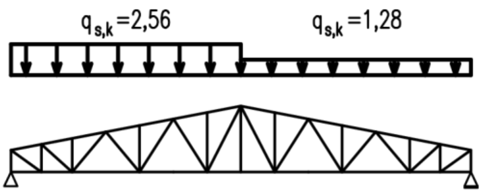
LS1 Permanent load



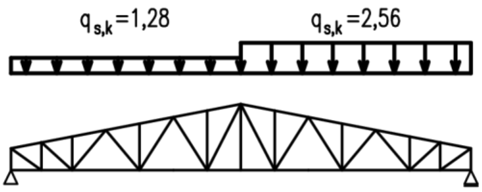
LS2 Snow load - full



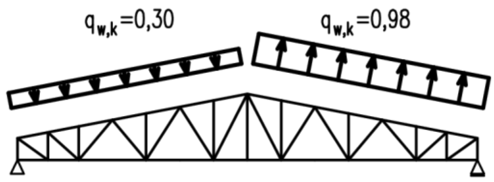
LS3 Snow load – left



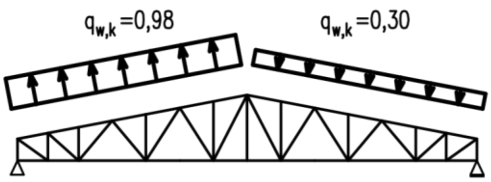
LS4 Snow load – right



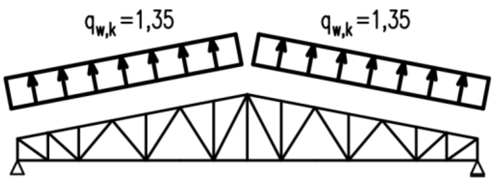
LS5 Wind load – lateral left



LS6 Wind load – lateral right



LS6 Wind load - longitudinal



Load combinations are created according next rules (according to the rule 6.10 in EN 1990). Snow load states (LS2, LS3 and LS4) and wind load states (LS5, LS6 and LS7) have not to be combined together!!!:

$$\mathrm{LC1} = 1{,}35 \cdot \mathrm{LS1} + 1{,}5 \cdot \mathrm{LS2}$$

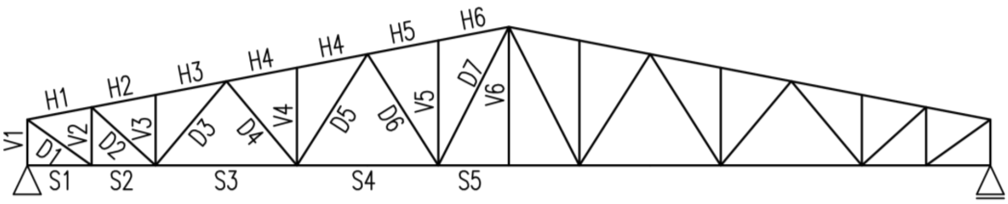
$$\mathrm{LC2} = 1{,}35 \cdot \mathrm{LS1} + 1{,}5 \cdot \left(\mathrm{LS3} + \psi_0 \cdot \mathrm{LS5}\right)$$

$$\mathrm{LC3} = 1{,}35 \cdot \mathrm{LS1} + 1{,}5 \cdot \left(\mathrm{LS4} + \psi_0 \cdot \mathrm{LS6}\right)$$

$$\mathrm{LC4} = 1{,}00 \cdot \mathrm{LS1} + 1{,}5 \cdot \mathrm{LS7}$$

where ψ_0 is factor for combination value of an imposed load (see EN 1990)

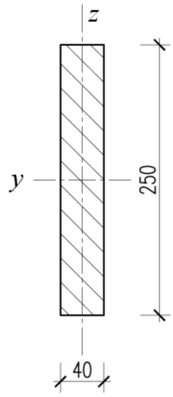
Truss girder members notation



Normal forces in truss girder members

Member	Load state							Load combination			
	LS1	LS2	LS3	LS4	LS5	LS6	LS7	LC1	LC2	LC3	LC4
	[kN]							[kN]			
H1	-8,47	-20,47	-17,62	-12,95	0,51	4,91	10,75	-42,14	-37,40	-26,43	7,65
H2	-12,92	-31,24	-26,77	-20,09	1,10	7,28	16,60	-64,31	-56,62	-41,03	11,98
H3	-12,92	-31,24	-26,77	-20,09	1,04	7,49	16,88	-64,31	-56,68	-40,84	12,39
H4	-16,24	-39,25	-32,49	-26,40	2,55	8,15	21,18	-80,80	-68,36	-54,18	15,53
H5	-16,24	-39,25	-32,49	-26,40	2,49	8,36	21,47	-80,80	-68,41	-53,99	15,97
H6	-15,42	-37,27	-29,20	-26,70	4,10	6,24	20,48	-76,71	-60,92	-55,25	15,30
H7	-15,42	-37,27	-29,20	-26,70	4,03	6,45	20,77	-76,71	-60,98	-55,06	15,73
D1	10,08	24,37	21,10	15,45	-0,65	-5,80	-12,79	50,15	44,67	31,55	-9,10
D2	5,88	14,21	11,89	9,43	-0,85	-2,88	-7,39	29,25	25,00	19,49	-5,21
D3	-3,70	-8,93	-6,90	-6,50	1,17	1,13	16,79	-18,39	-14,28	-13,73	21,48
D4	1,36	3,28	1,81	3,11	-1,23	0,44	-1,56	6,74	3,43	6,89	-0,98
D5	0,15	0,37	1,70	-1,15	1,52	-1,73	-0,41	0,76	4,13	-3,07	-0,46
D6	-1,35	-3,26	-4,31	-0,59	-1,55	2,53	1,94	-6,72	-9,68	-0,43	1,56
D7	2,59	6,26	7,24	2,14	1,85	-3,65	-3,57	12,88	16,03	3,42	-2,76
V1	-7,94	-19,20	-16,80	-12,00	0,33	4,77	10,10	-39,52	-35,63	-24,43	7,21
V2	-5,84	-14,11	-12,22	-8,94	0,38	3,36	7,40	-29,04	-25,86	-18,27	5,27
V3	-1,11	-2,69	-2,69	-1,34	-0,33	1,07	1,47	-5,53	-5,83	-2,56	1,09
V4	-1,17	-2,82	-2,82	-1,41	-0,34	1,12	1,54	-5,80	-6,10	-2,68	1,14
V5	-1,17	-2,82	-2,82	-1,41	-0,34	1,12	1,54	-5,80	-6,10	-2,68	1,14
V6	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
S1	0,00	0,00	0,00	0,00	1,84	-1,84	0,00	0,00	1,66	-1,66	0,00
S2	8,22	19,87	17,21	12,59	1,31	-6,57	-10,43	40,89	38,08	24,07	-7,42
S3	14,97	36,18	30,48	23,79	-0,08	-9,44	-18,85	74,47	65,85	47,39	-13,31
S4	15,76	38,09	30,73	26,41	-1,69	-8,23	-19,64	78,41	65,85	53,48	-13,70
S5	13,85	33,49	25,12	25,12	-3,36	-5,21	-16,97	68,93	53,35	51,69	-11,60

DIAGONAL D1



Cross section geometry

b = 40 mm diagonal section width

h = 250 mm diagonal section depth

$$A = b \cdot h = 40 \cdot 250 = 10000 \text{ mm}^2$$

Tension

N_{Ed} = 50,15 kN from LC1

Design tensile stress along the grain

$$\sigma_{t,0,d} = \frac{N_{Ed}}{A} = \frac{50{,}15.10^3}{10000} = 5{,}02 \text{ MPa}$$

Reliability criterion

$$\frac{\sigma_{t,0,d}}{f_{t,0,d}} = \frac{5{,}02}{8{,}31} = 0{,}60 \quad \leq \quad 1{,}0$$

=> condition is satisfied

Compression => flexural buckling

N_{Ed} = -9,10 kN from LC4

Design compression stress along the grain

$$\sigma_{c,0,d} = \frac{N_{Ed}}{A} = \frac{9{,}10.10^3}{10000} = 0{,}91 \text{ MPa}$$

Critical length

$$L_{cr,y} = L_{cr,z} = L_{sys} = 1226 \text{ mm}$$

Moment of inertia

$$I_y = \frac{1}{12} b \cdot h^3 = \frac{1}{12} 40 \cdot 250^3 = 52{,}08.10^6 \text{ mm}^4$$

$$I_z = \frac{1}{12} b^3 \cdot h = \frac{1}{12} 40^3 \cdot 250 = 1{,}33.10^6 \text{ mm}^4$$

Radius of gyration

$$i_y = \sqrt{\frac{I_y}{A}} = \sqrt{\frac{52{,}08.10^6}{10000}} = 72{,}2 \text{ mm}$$

$$i_z = \sqrt{\frac{I_z}{A}} = \sqrt{\frac{1{,}33.10^6}{10000}} = 11{,}5 \text{ mm}$$

Slenderness

$$\lambda_{y} = \frac{L_{cr,y}}{i_{y}} = \frac{1226}{72,2} = 17$$

$$\lambda_{z} = \frac{L_{cr,z}}{i_{z}} = \frac{1226}{11,5} = 107$$ => buckling lateral to the *z*-axis is decisive

Relative slenderness

$$\lambda_{rel,z} = \frac{\lambda_{z}}{\pi} \cdot \sqrt{\frac{f_{c,0,k}}{E_{0,05}}} = \frac{107}{\pi} \cdot \sqrt{\frac{19}{6400}} = 1,856$$

Factor for reduction factor calculation

$$k_{z} = 0,5 \cdot \left(1 + \beta_{c}\left(\lambda_{rel,z} - 0,3\right) + \lambda_{rel,z}^{2}\right) = 0,5 \cdot \left(1 + 0,2(1,856 - 0,3) + 1,856^{2}\right) = 2,378$$

Reduction factor

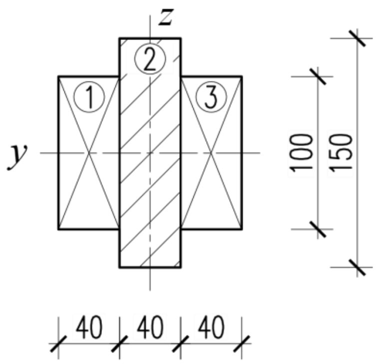
$$k_{c,z} = \frac{1}{k_{z} + \sqrt{k_{z}^{2} - \lambda_{rel,z}^{2}}} = \frac{1}{2,378 + \sqrt{2,378^{2} - 1,856^{2}}} = 0,259$$

Reliability criterion

$$\frac{\sigma_{c,0,d}}{k_{c,z} \cdot f_{c,0,d}} = \frac{0,91}{0,259 \cdot 13,15} = 0,27 \quad \leq \quad 1,0$$ ***=> condition is satisfied***

DIAGONAL D3

Cross section geometry



$b_{1,3}$ = 40 mm pack width

$h_{1,3}$ = 100 mm pack depth

b_2 = 40 mm shaft width

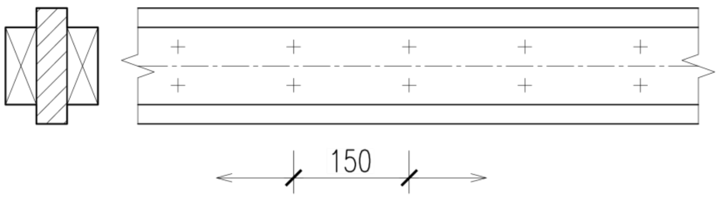
h_2 = 150 mm shaft depth

$$A_{1,3} = b_{1,3} \cdot h_{1,3} = 40 \cdot 100 = 4000 \text{ mm}^2$$

$$A_2 = b_2 \cdot h_2 = 40 \cdot 150 = 6000 \text{ mm}^2$$

$$A_{\text{tot}} = A_1 + A_2 + A_3 = 4000 + 6000 + 4000 = 14000 \text{ mm}^2$$

Nails in two rows with 150 mm spacing



Compression => flexural buckling

N_{Ed} = -18,39 kN from LC1

Design compression stress along the grain

$$\sigma_{\text{c,0,d}} = \frac{N_{\text{Ed}}}{A_{\text{tot}}} = \frac{18{,}39.10^3}{14000} = 1{,}31 \text{ MPa}$$

Buckling lateral to the *y*-direction

Critical length

$$L_{\text{cr,y}} = L_{\text{sys}} = 1707 \text{ mm}$$

Moment of inertia

$$I_y = \frac{1}{12} \sum b_i \cdot h_i^3 = \frac{1}{12} \left(40 \cdot 100^3 + 40 \cdot 150^3 + 40 \cdot 100^3 \right) = 17{,}92.10^6 \text{ mm}^4$$

Radius of gyration

$$i_y = \sqrt{\frac{I_y}{A_{\text{tot}}}} = \sqrt{\frac{17{,}92.10^6}{14000}} = 35{,}8 \text{ mm}$$

Slenderness

$$\lambda_y = \frac{L_{\text{cr,y}}}{i_y} = \frac{1707}{35{,}8} = 48$$

Relative slenderness

$$\lambda_{rel,z} = \frac{\lambda_z}{\pi} \cdot \sqrt{\frac{f_{c,0,k}}{E_{0,05}}} = \frac{48}{\pi} \cdot \sqrt{\frac{19}{6400}} = 0{,}832$$

Factor for reduction factor calculation

$$k_z = 0{,}5 \cdot \left(1 + \beta_c \cdot (\lambda_{rel,z} - 0{,}3) + \lambda_{rel,z}^2\right) = 0{,}5 \cdot \left(1 + 0{,}2 \cdot (0{,}832 - 0{,}3) + 0{,}832^2\right) = 0{,}899$$

Reduction factor

$$k_{c,z} = \frac{1}{k_z + \sqrt{k_z^2 - \lambda_{rel,z}^2}} = \frac{1}{0{,}899 + \sqrt{0{,}899^2 - 0{,}832^2}} = 0{,}807$$

Reliability criterion

$$\frac{\sigma_{c,0,d}}{k_{c,z} \cdot f_{c,0,d}} = \frac{1{,}31}{0{,}807 \cdot 13{,}15} = 0{,}12 \quad \leq \quad 1{,}0$$

=> condition is satisfied

Buckling lateral to the *z*-direction

Critical length

$$L_{cr,z} = L_{sys} = 1707 \text{ mm}$$

Shear transfer coefficient

$$\gamma_{1,3} = \left[1 + \frac{\pi^2 \cdot E_{0,mean;1,3} \cdot A_{1,3} \cdot s_{1,3}}{K_{1,3} \cdot L_{cr,z}^2}\right]^{-1} = \left[1 + \frac{\pi^2 \cdot 9500 \cdot 4000 \cdot 75}{519 \cdot 1707^2}\right]^{-1} = 0{,}051$$

$$\gamma_2 = 1$$

where

$$K_{ser} = \rho_m^{1,5} \cdot \frac{d^{0,8}}{30} = 390 \cdot \frac{4^{0,8}}{30} = 778 \text{ N/mm}$$ is slip modulus for nails without pre-drilling

$$K_{1,3} = K_u = \frac{2}{3} \cdot K_{ser} = \frac{2}{3} \cdot 778 = 519 \text{ N/mm}$$ is slip modulus for ULS

$$s_{1,3} = \frac{a_1}{n_{row}} = \frac{150}{2} = 75 \text{ mm}$$ is nail distance (number of rows included)

Effective moment of inertia

$$I_{eff,z} = I_{1,eff,z} + I_{2,eff,z} + I_{3,eff,z} = 0{,}860 + 0{,}8 + 0{,}860 = 2{,}52.10^6 \text{ mm}^4$$

where

$$I_{1,eff,z} = \frac{1}{12} \cdot b_1^3 \cdot h_1 + \gamma_1 \cdot A_1 \cdot a_1^2 = \frac{1}{12} \cdot 40^3 \cdot 100 + 0{,}051 \cdot 4000 \cdot 40^2 = 0{,}860.10^6 \text{ mm}^4$$

$$I_{2,\text{eff,z}} = \frac{1}{12} \cdot b_2^3 \cdot h_2 + \gamma_2 \cdot A_2 \cdot a_2^2 = \frac{1}{12} \cdot 40^3 \cdot 150 + 1 \cdot 6000 \cdot 0^2 = 0{,}800.10^6 \text{ mm}^4$$

$$I_{3,\text{eff,z}} = \frac{1}{12} \cdot b_3^3 \cdot h_3 + \gamma_3 \cdot A_3 \cdot a_3^2 = \frac{1}{12} \cdot 40^3 \cdot 100 + 0{,}051 \cdot 4000 \cdot 40^2 = 0{,}860.10^6 \text{ mm}^4$$

Radius of gyration

$$i_{\text{eff,z}} = \sqrt{\frac{I_{\text{eff,z}}}{A_{\text{tot}}}} = \sqrt{\frac{2{,}52.10^6}{14000}} = 13{,}4 \text{ mm}$$

Slenderness

$$\lambda_{\text{eff,z}} = \frac{L_{\text{cr,z}}}{i_{\text{eff,z}}} = \frac{1707}{13{,}4} = 127$$

Relative slenderness

$$\lambda_{\text{rel,z}} = \frac{\lambda_{\text{eff,z}}}{\pi} \cdot \sqrt{\frac{f_{\text{c,0,k}}}{E_{0,05}}} = \frac{127}{\pi} \cdot \sqrt{\frac{19}{6400}} = 2{,}203$$

Factor for reduction factor calculation

$$k_z = 0{,}5 \cdot \left(1 + \beta_c \cdot (\lambda_{\text{rel,z}} - 0{,}3) + \lambda_{\text{rel,z}}^2\right) = 0{,}5 \cdot \left(1 + 0{,}2 \cdot (2{,}203 - 0{,}3) + 2{,}203^2\right) = 3{,}117$$

Reduction factor

$$k_{\text{c,z}} = \frac{1}{k_z + \sqrt{k_z^2 - \lambda_{\text{rel,z}}^2}} = \frac{1}{3{,}117 + \sqrt{3{,}117^2 - 2{,}203^2}} = 0{,}188$$

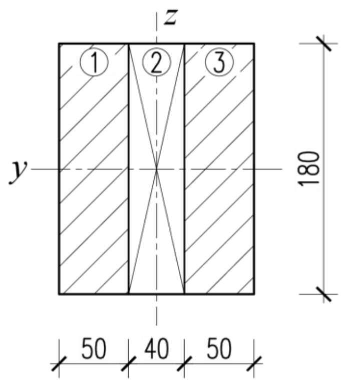
Reliability criterion

$$\frac{\sigma_{\text{c,0,d}}}{k_{\text{c,z}} \cdot f_{\text{c,0,d}}} = \frac{1{,}31}{0{,}188 \cdot 13{,}15} = 0{,}53 \quad \leq \quad 1{,}0$$

=> condition is satisfied

UPPER CHORD H5

Cross section geometry



$b_{1,3}$ = 50 mm shaft width

$h_{1,3}$ = 180 mm shaft depth

b_2 = 40 mm pack width

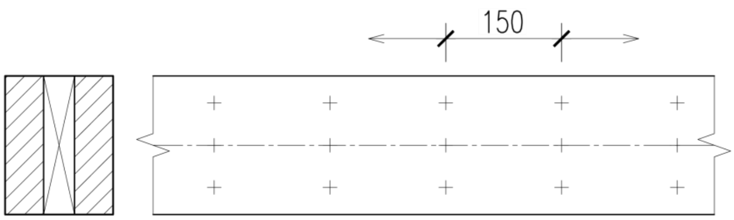
h_2 = 180 mm pack depth

$$A_{1,3} = b_{1,3} \cdot h_{1,3} = 50 \cdot 180 = 9000 \text{ mm}^2$$

$$A_2 = b_2 \cdot h_2 = 40 \cdot 180 = 7200 \text{ mm}^2$$

$$A_{tot} = A_1 + A_2 + A_3 = 7200 + 9000 + 7200 = 23400 \text{ mm}^2$$

Nails in three rows with 150 mm spacing



Compression => flexural buckling

N_{Ed} = -80,80 kN from LC1

Design compression stress along the grain

$$\sigma_{c,0,d} = \frac{N_{Ed}}{A_{tot}} = \frac{80{,}80.10^3}{23400} = 3{,}45 \text{ MPa}$$

Buckling lateral to the *y*-direction

Critical length

$$L_{cr,y} = L_{sys} = 1120 \text{ mm}$$

Moment of inertia

$$I_y = \frac{1}{12} \sum b_i \cdot h_i^3 = \frac{1}{12}\left(50 \cdot 180^3 + 40 \cdot 180^3 + 50 \cdot 180^3\right) = 68{,}04.10^6 \text{ mm}^4$$

Radius of gyration

$$i_y = \sqrt{\frac{I_y}{A_{tot}}} = \sqrt{\frac{68{,}04.10^6}{23400}} = 53{,}9 \text{ mm}$$

Slenderness

$$\lambda_{y} = \frac{L_{cr,y}}{i_{y}} = \frac{1120}{53,9} = 21$$

Relative slenderness

$$\lambda_{rel,z} = \frac{\lambda_{z}}{\pi} \cdot \sqrt{\frac{f_{c,0,k}}{E_{0,05}}} = \frac{21}{\pi} \cdot \sqrt{\frac{19}{6400}} = 0,360$$

Factor for reduction factor calculation

$$k_{z} = 0,5 \cdot \left(1 + \beta_{c} \cdot \left(\lambda_{rel,z} - 0,3\right) + \lambda_{rel,z}^{2}\right) = 0,5 \cdot \left(1 + 0,2 \cdot \left(0,360 - 0,3\right) + 0,360^{2}\right) = 0,571$$

Reduction factor

$$k_{c,z} = \frac{1}{k_{z} + \sqrt{k_{z}^{2} - \lambda_{rel,z}^{2}}} = \frac{1}{0,571 + \sqrt{0,571^{2} - 0,360^{2}}} = 0,986$$

Reliability criterion

$$\frac{\sigma_{c,0,d}}{k_{c,z} \cdot f_{c,0,d}} = \frac{3,45}{0,986 \cdot 13,15} = 0,27 \quad \leq \quad 1,0$$

=> condition is satisfied

Buckling lateral to the *z*-direction

Critical length

$$L_{cr,z} = 2 \cdot L_{sys} = 2240 \text{ mm}$$

depending on transversal roof bracing system

Shear transfer coefficient

$$\gamma_{1,3} = \left[1 + \frac{\pi^{2} \cdot E_{0,mean;1,3} \cdot A_{1,3} \cdot s_{1,3}}{K_{1,3} \cdot L_{cr,z}^{2}}\right]^{-1} = \left[1 + \frac{\pi^{2} \cdot 9500 \cdot 9000 \cdot 50}{519 \cdot 2240^{2}}\right]^{-1} = 0,058$$

$$\gamma_{2} = 1$$

where

$$K_{ser} = \rho_{m}^{1,5} \cdot \frac{d^{0,8}}{30} = 390 \cdot \frac{4^{0,8}}{30} = 778 \text{ N/mm}$$ is slip modulus for nails without pre-drilling

$$K_{1,3} = K_{u} = \frac{2}{3} \cdot K_{ser} = \frac{2}{3} \cdot 778 = 519 \text{ N/mm}$$ is slip modulus for ULS

$$s_{1,3} = \frac{a_{1}}{n_{row}} = \frac{150}{3} = 50 \text{ mm}$$ is nail distance (number of rows included)

Effective moment of inertia

$$I_{eff,z} = I_{1,eff,z} + I_{2,eff,z} + I_{3,eff,z} = 2,93 + 0,96 + 2,93 = 6,82.10^{6} \text{ mm}^{4}$$

where

$$I_{1,\mathrm{eff,z}} = \frac{1}{12} \cdot b_1^3 \cdot h_1 + \gamma_1 \cdot A_1 \cdot a_1^2 = \frac{1}{12} \cdot 50^3 \cdot 180 + 0{,}058 \cdot 9000 \cdot 45^2 = 2{,}93.10^6 \ \mathrm{mm}^4$$

$$I_{2,\mathrm{eff,z}} = \frac{1}{12} \cdot b_2^3 \cdot h_2 + \gamma_2 \cdot A_2 \cdot a_2^2 = \frac{1}{12} \cdot 40^3 \cdot 180 + 1 \cdot 7200 \cdot 0^2 = 0{,}96.10^6 \ \mathrm{mm}^4$$

$$I_{3,\mathrm{eff,z}} = \frac{1}{12} \cdot b_3^3 \cdot h_3 + \gamma_3 \cdot A_3 \cdot a_3^2 = \frac{1}{12} \cdot 50^3 \cdot 180 + 0{,}058 \cdot 9000 \cdot 45^2 = 2{,}93.10^6 \ \mathrm{mm}^4$$

Radius of gyration

$$i_{\mathrm{eff,z}} = \sqrt{\frac{I_{\mathrm{eff,z}}}{A_{\mathrm{tot}}}} = \sqrt{\frac{6{,}82.10^6}{23400}} = 17{,}1 \ \mathrm{mm}$$

Slenderness

$$\lambda_{\mathrm{eff,z}} = \frac{L_{\mathrm{cr,z}}}{i_{\mathrm{eff,z}}} = \frac{2240}{17{,}1} = 131$$

Relative slenderness

$$\lambda_{\mathrm{rel,z}} = \frac{\lambda_{\mathrm{eff,z}}}{\pi} \cdot \sqrt{\frac{f_{\mathrm{c,0,k}}}{E_{0,05}}} = \frac{131}{\pi} \cdot \sqrt{\frac{19}{6400}} = 2{,}272$$

Factor for reduction factor calculation

$$k_z = 0{,}5 \cdot \left(1 + \beta_c \cdot (\lambda_{\mathrm{rel,z}} - 0{,}3) + \lambda_{\mathrm{rel,z}}^2\right) = 0{,}5 \cdot \left(1 + 0{,}2 \cdot (2{,}272 - 0{,}3) + 2{,}272^2\right) = 3{,}278$$

Reduction factor

$$k_{\mathrm{c,z}} = \frac{1}{k_z + \sqrt{k_z^2 - \lambda_{\mathrm{rel,z}}^2}} = \frac{1}{3{,}278 + \sqrt{3{,}278^2 - 2{,}272^2}} = 0{,}178$$

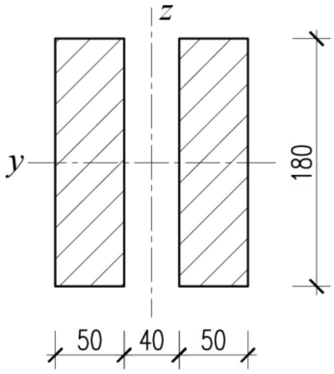
Reliability criterion

$$\frac{\sigma_{\mathrm{c,0,d}}}{k_{\mathrm{c,z}} \cdot f_{\mathrm{c,0,d}}} = \frac{3{,}45}{0{,}178 \cdot 13{,}15} = 1{,}47 \quad \geq \quad 1{,}0$$

=> condition is not satisfied

BOTTOM CHORD S4

Cross section geometry



$b_{1,2}$ = 50 mm shaft width

$h_{1,2}$ = 180 mm shaft depth

$$A_{1,2} = b_{1,2} \cdot h_{1,2} = 50 \cdot 180 = 9000 \text{ mm}^2$$

$$A_{tot} = A_1 + A_2 = 9000 + 9000 = 18000 \text{ mm}^2$$

Tension

N_{Ed} = 78,41 kN from LC1

Design tensile stress along the grain

$$\sigma_{t,0,d} = \frac{N_{Ed}}{A} = \frac{78{,}41.10^3}{18000} = 4{,}36 \text{ MPa}$$

Reliability criterion

$$\frac{\sigma_{t,0,d}}{f_{t,0,d}} = \frac{4{,}36}{8{,}31} = 0{,}52 \quad \leq \quad 1{,}0$$

=> condition is satisfied

Compression => flexural buckling

N_{Ed} = -13,70 kN from LC4

Design compression stress along the grain

$$\sigma_{c,0,d} = \frac{N_{Ed}}{A_{tot}} = \frac{13{,}70.10^3}{18000} = 0{,}76 \text{ MPa}$$

Buckling lateral to the *y*-direction

Critical length

$$L_{cr,y} = L_{sys} = 2200 \text{ mm}$$

Moment of inertia

$$I_y = \frac{1}{12}\sum b_i \cdot h_i^3 = \frac{1}{12}\left(50 \cdot 180^3 + 50 \cdot 180^3\right) = 48{,}60.10^6 \text{ mm}^4$$

Radius of gyration

$$i_y = \sqrt{\frac{I_y}{A_{tot}}} = \sqrt{\frac{48{,}60.10^6}{18000}} = 52{,}0 \text{ mm}$$

Slenderness

$$\lambda_y = \frac{L_{cr,y}}{i_y} = \frac{2200}{52{,}0} = 42$$

Relative slenderness

$$\lambda_{rel,z} = \frac{\lambda_z}{\pi} \cdot \sqrt{\frac{f_{c,0,k}}{E_{0,05}}} = \frac{42}{\pi} \cdot \sqrt{\frac{19}{6400}} = 0{,}728$$

Factor for reduction factor calculation

$$k_z = 0{,}5 \cdot \left(1 + \beta_c \cdot \left(\lambda_{rel,z} - 0{,}3\right) + \lambda_{rel,z}^2\right) = 0{,}5 \cdot \left(1 + 0{,}2 \cdot \left(0{,}728 - 0{,}3\right) + 0{,}728^2\right) = 0{,}808$$

Reduction factor

$$k_{c,z} = \frac{1}{k_z + \sqrt{k_z^2 - \lambda_{rel,z}^2}} = \frac{1}{0{,}808 + \sqrt{0{,}808^2 - 0{,}728^2}} = 0{,}863$$

Reliability criterion

$$\frac{\sigma_{c,0,d}}{k_{c,z} \cdot f_{c,0,d}} = \frac{0{,}76}{0{,}863 \cdot 13{,}15} = 0{,}07 \quad \leq \quad 1{,}0$$

=> condition is satisfied

Buckling lateral to the *z*-direction

Critical length

$L_{cr,z} = 7500 \text{ mm}$ *depending on longitudinal (vertical) roof bracing system*

Total moment of inertia

Effective moment of inertia

$$I_{tot,z} = I_{1,z} + I_{2,z} = 20{,}1 + 20{,}1 = 40{,}2.10^6 \text{ mm}^4$$

where

$$I_{1,z} = \frac{1}{12} \cdot b_1^3 \cdot h_1 + A_1 \cdot a_1^2 = \frac{1}{12} \cdot 50^3 \cdot 180 + 9000 \cdot 45^2 = 20{,}1.10^6 \text{ mm}^4$$

$$I_{2,z} = \frac{1}{12} \cdot b_2^3 \cdot h_2 + A_2 \cdot a_2^2 = \frac{1}{12} \cdot 50^3 \cdot 180 + 9000 \cdot 45^2 = 20{,}1.10^6 \text{ mm}^4$$

Effective slenderness

$$\lambda_{eff,z} = \sqrt{\lambda^2 + \eta \cdot \frac{n}{2} \cdot \lambda_1^2} = \sqrt{159^2 + 3 \cdot \frac{2}{2} \cdot 76^2} = 206$$

where

$n = 2$ is number of shafts

$\eta = 3$ is factor for nailed packs for short-term loading

$\lambda = L_{cr,z} \cdot \sqrt{\frac{A_{tot}}{I_{tot}}} = 7500 \cdot \sqrt{\frac{18000}{40{,}2.10^6}} = 159$ is slenderness for solid column

$$\lambda_1 = \sqrt{12} \cdot \frac{l_1}{b} = \sqrt{12} \cdot \frac{1100}{50} = 76 \geq 30$$ is slenderness for the shafts

Relative slenderness

$$\lambda_{\mathrm{rel,z}} = \frac{\lambda_{\mathrm{eff,z}}}{\pi} \cdot \sqrt{\frac{f_{\mathrm{c,0,k}}}{E_{0,05}}} = \frac{206}{\pi} \cdot \sqrt{\frac{19}{6400}} = 3{,}573$$

Factor for reduction factor calculation

$$k_{\mathrm{z}} = 0{,}5 \cdot \left(1 + \beta_{\mathrm{c}} \cdot \left(\lambda_{\mathrm{rel,z}} - 0{,}3\right) + \lambda_{\mathrm{rel,z}}^2\right) = 0{,}5 \cdot \left(1 + 0{,}2 \cdot \left(3{,}573 - 0{,}3\right) + 3{,}573^2\right) = 7{,}210$$

Reduction factor

$$k_{\mathrm{c,z}} = \frac{1}{k_{\mathrm{z}} + \sqrt{k_{\mathrm{z}}^2 - \lambda_{\mathrm{rel,z}}^2}} = \frac{1}{7{,}210 + \sqrt{7{,}210^2 - 3{,}573^2}} = 0{,}074$$

Reliability criterion

$$\frac{\sigma_{\mathrm{c,0,d}}}{k_{\mathrm{c,z}} \cdot f_{\mathrm{c,0,d}}} = \frac{0{,}76}{0{,}074 \cdot 13{,}15} = 0{,}78 \quad \leq \quad 1{,}0$$

=> ***condition is satisfied***

There are additional moments due to eccentricities in joints which have to be take into account at bottom and upper chord!!!