

Project

Job name : New Hall
 Part : Part D
 Author : John Smith
 Date : 29.01.2018

Standard

Standard **EN 1993-1-1, EN 1993-1-4/Czech Rep.**

Factors for steel structures

Section capacity : $\gamma_{M0} = 1,000$
 Section resistance when checking stability : $\gamma_{M1} = 1,000$
 Perforated section capacity : $\gamma_{M2} = 1,250$

Factors for stainless steel

Section capacity : $\gamma_{M0} = 1,100$
 Section resistance when checking stability : $\gamma_{M1} = 1,100$
 Perforated section capacity : $\gamma_{M2} = 1,250$

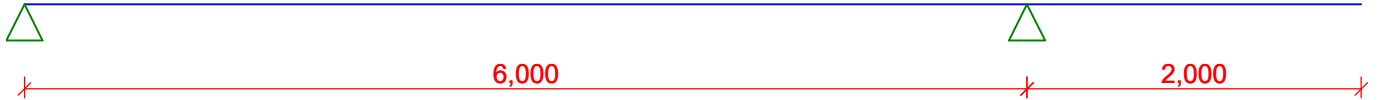
1 Beam 1

1.1 Input data

Length: 8,000 m

1.1.1 Geometry

| x [m] | Point kind | A/L [m] | I/L [m ³] |
|-------|------------|---------|-----------------------|
| 0,000 | hinged | - | - |
| 6,000 | hinged | - | - |
| 8,000 | free | - | - |



Cross-section

| Sector no. | Start [m] | End [m] | Section | Rotation [°] |
|------------|-----------|---------|----------|--------------|
| 1 | 0,000 | 8,000 | HE 140 B | 0,0 |

Material

Name: EN 10210-1 : S 235

1.1.2 Load

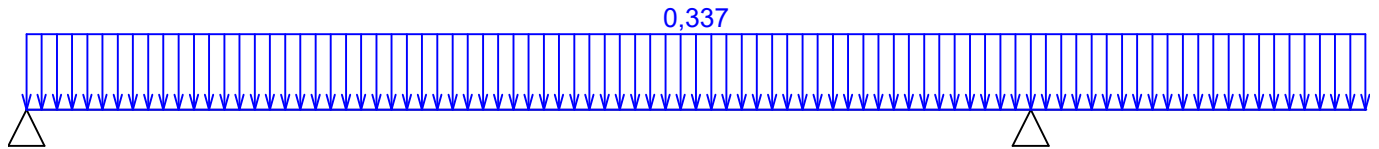
Load cases

| no. | Name | Code | Type | $\gamma_f (\gamma_{f,inf})^*$ | Factors for combinations | | | | |
|-----|----------------|-------------|-----------|-------------------------------|--------------------------|----------|----------|----------|----------|
| | | | | | ξ | Categ.** | ψ_0 | ψ_1 | ψ_2 |
| 1 | G1 Self-weight | Self weight | Permanent | 1,35(0,90) | 0,85 | - | - | - | - |
| 2 | G2 Permanent | Force | Permanent | 1,35(0,90) | 0,85 | - | - | - | - |
| 3 | Q3 Imposed 01 | Force | Variable | 1,50 | - | A | 0,70 | 0,50 | 0,30 |
| 4 | Q4 Imposed 02 | Force | Variable | 1,50 | - | A | 0,70 | 0,50 | 0,30 |
| 5 | Q5 Imposed 03 | Force | Variable | 1,50 | - | A | 0,70 | 0,50 | 0,30 |

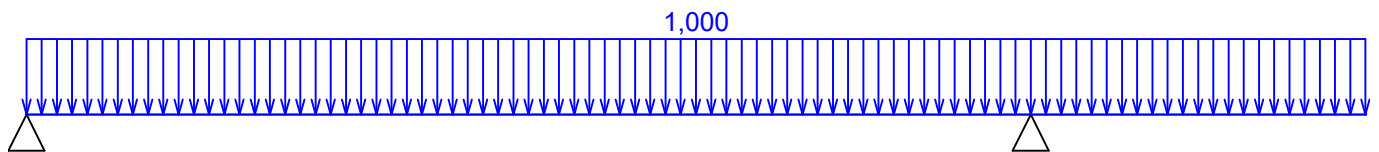
* $\gamma_{f,inf}$ for favourable dead loads

** Category of live loads according to table A1.1 in EN 1990

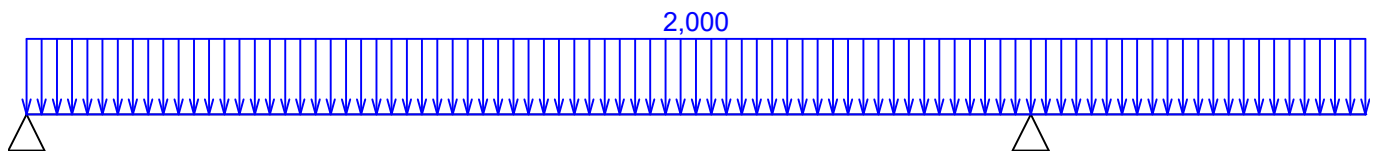
| G1 Self-weight - load | | | | |
|-----------------------|------------|------------|-----------|-------|
| Type | Coor.x [m] | Length [m] | Size1 | Size2 |
| uniform | 0,000 | 8,000 | 0,337kN/m | - |



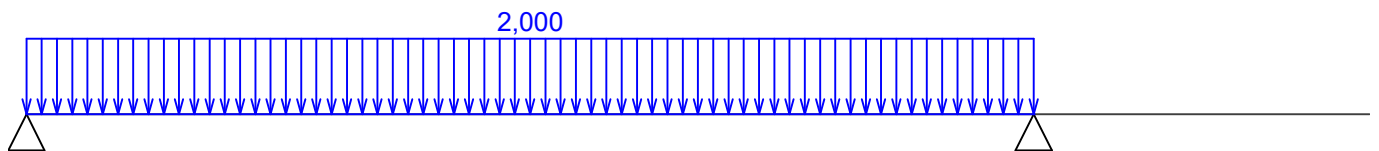
| G2 Permanent - load | | | | |
|---------------------|------------|------------|-----------|-------|
| Type | Coor.x [m] | Length [m] | Size1 | Size2 |
| uniform | 0,000 | 8,000 | 1,000kN/m | - |



| Q3 Imposed 01 - load | | | | |
|----------------------|------------|------------|-----------|-------|
| Type | Coor.x [m] | Length [m] | Size1 | Size2 |
| uniform | 0,000 | 8,000 | 2,000kN/m | - |



| Q4 Imposed 02 - load | | | | |
|----------------------|------------|------------|-----------|-------|
| Type | Coor.x [m] | Length [m] | Size1 | Size2 |
| uniform | 0,000 | 6,000 | 2,000kN/m | - |



| Q5 Imposed 03 - load | | | | |
|----------------------|------------|------------|-----------|-------|
| Type | Coor.x [m] | Length [m] | Size1 | Size2 |
| uniform | 6,000 | 2,000 | 2,000kN/m | - |



1.1.3 Combinations

Combinations

1.1.4 Combinations for 1st order calculation

Combination for check of ultimate limit state (ULS), 1st order

| Number | Comb. name and type Composition |
|--------|--|
| 1 | G1+G2; basic combination $\gamma_{f,sup,1} * G1 + \gamma_{f,sup,2} * G2$ |
| 2 | Q5:G1+G2; basic combination $\gamma_{f,sup,1} * G1 + \gamma_{f,sup,2} * G2 + \gamma_{f,sup,5} * Q5$ |
| 3 | Q4:G1+G2; basic combination $\gamma_{f,sup,1} * G1 + \gamma_{f,sup,2} * G2 + \gamma_{f,sup,4} * Q4$ |
| 4 | Q3:G1+G2; basic combination $\gamma_{f,sup,1} * G1 + \gamma_{f,sup,2} * G2 + \gamma_{f,sup,3} * Q3$ |

Combination for check of serviceability limit state (SLS), 1st order

| Number | Comb. name and type Composition |
|--------|--|
| 1 | G1+G2; characteristic combination G1 + G2 |
| 2 | Q5:G1+G2; characteristic combination G1 + G2 + Q5 |
| 3 | Q4:G1+G2; characteristic combination G1 + G2 + Q4 |
| 4 | Q3:G1+G2; characteristic combination G1 + G2 + Q3 |

Internal forces

Total number of loads: 8

G1+G2:

| | V ₃ [kN] | M ₂ [kNm] | R _z [kN] | RO _x [kNm] |
|------------|---------------------|----------------------|---------------------|-----------------------|
| Max. value | 4,457 | 4,745 | 7,132 | - |
| Min. value | -3,566 | -2,674 | 3,566 | - |

Q5:G1+G2:

| | V ₃ [kN] | M ₂ [kNm] | R _z [kN] | RO _x [kNm] |
|------------|---------------------|----------------------|---------------------|-----------------------|
| Max. value | 5,124 | 3,137 | 11,799 | - |
| Min. value | -6,674 | -6,674 | 2,899 | - |

Q4:G1+G2:

| | V ₃ [kN] | M ₂ [kNm] | R _z [kN] | RO _x [kNm] |
|------------|---------------------|----------------------|---------------------|-----------------------|
| Max. value | 10,457 | 13,680 | 13,132 | - |
| Min. value | -9,566 | -2,674 | 9,566 | - |

Q3:G1+G2:

| | V ₃ [kN] | M ₂ [kNm] | R _z [kN] | RO _x [kNm] |
|------------|---------------------|----------------------|---------------------|-----------------------|
| Max. value | 11,124 | 11,842 | 17,799 | - |
| Min. value | -8,899 | -6,674 | 8,899 | - |

G1+G2:

| | V ₃ [kN] | M ₂ [kNm] | R _z [kN] | RO _x [kNm] |
|------------|---------------------|----------------------|---------------------|-----------------------|
| Max. value | 6,018 | 6,406 | 9,628 | - |

| | V ₃ [kN] | M ₂ [kNm] | R _z [kN] | RO _x [kNm] |
|------------|---------------------|----------------------|---------------------|-----------------------|
| Min. value | -4,814 | -3,611 | 4,814 | - |

Q5:G1+G2:

| | V ₃ [kN] | M ₂ [kNm] | R _z [kN] | RO _x [kNm] |
|------------|---------------------|----------------------|---------------------|-----------------------|
| Max. value | 7,018 | 4,021 | 16,628 | - |
| Min. value | -9,611 | -9,611 | 3,814 | - |

Q4:G1+G2:

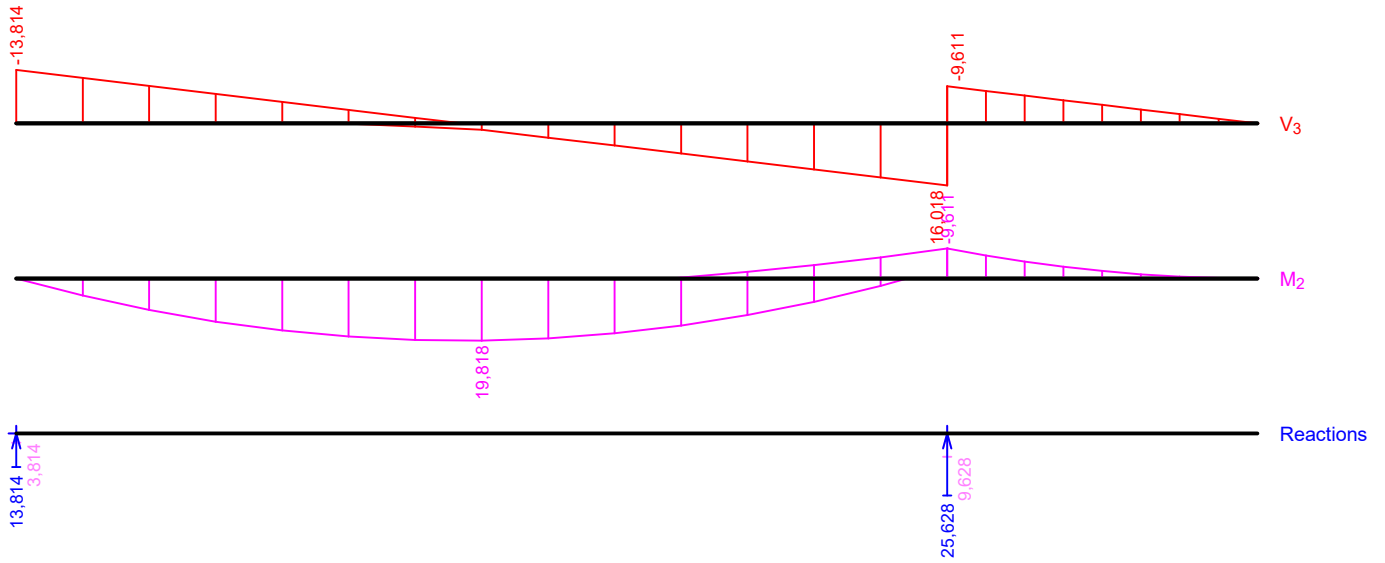
| | V ₃ [kN] | M ₂ [kNm] | R _z [kN] | RO _x [kNm] |
|------------|---------------------|----------------------|---------------------|-----------------------|
| Max. value | 15,018 | 19,818 | 18,628 | - |
| Min. value | -13,814 | -3,611 | 13,814 | - |

Q3:G1+G2:

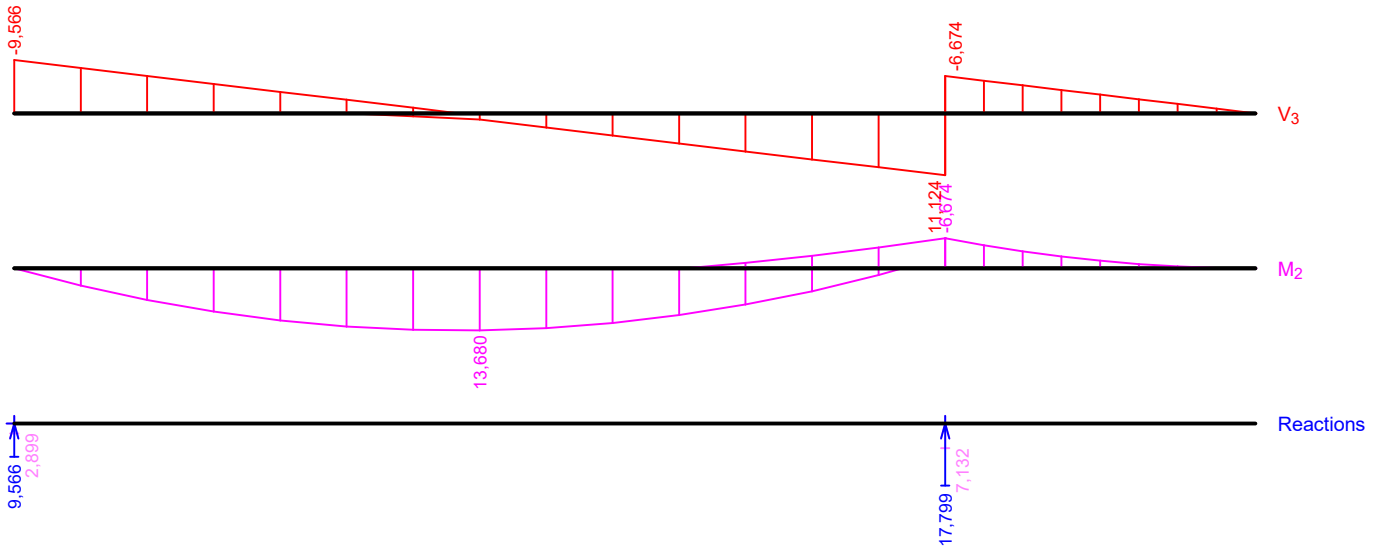
| | V ₃ [kN] | M ₂ [kNm] | R _z [kN] | RO _x [kNm] |
|------------|---------------------|----------------------|---------------------|-----------------------|
| Max. value | 16,018 | 17,051 | 25,628 | - |
| Min. value | -12,814 | -9,611 | 12,814 | - |

Envelopes

| Envelope basic design (ULS) | | | | | | | | |
|-----------------------------|-----------------------------|-----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|------------------------------|------------------------------|
| x [m] | Max M ₂ [kNm] | Min M ₂ [kNm] | Max V ₃ [kN] | Min V ₃ [kN] | Max R _z [kN] | Min R _z [kN] | Max RO _x [kNm] | Min RO _x [kNm] |
| 0,000 | 0,000 | 0,000 | -3,814 | -13,814 | 13,814 | 3,814 | - | - |
| 0,429 | 5,472 | 1,466 | -3,040 | -11,753 | - | - | - | - |
| 0,857 | 10,054 | 2,598 | -2,267 | -9,696 | - | - | - | - |
| 1,286 | 13,768 | 3,403 | -1,492 | -7,634 | - | - | - | - |
| 1,714 | 16,595 | 3,877 | -0,720 | -5,578 | - | - | - | - |
| 2,143 | 18,550 | 4,021 | 0,055 | -3,516 | - | - | - | - |
| 2,571 | 19,622 | 3,835 | 0,827 | -1,460 | - | - | - | - |
| 3,000 | 19,818 | 3,318 | 1,602 | 0,602 | - | - | - | - |
| 3,429 | 19,106 | 2,461 | 3,663 | 1,376 | - | - | - | - |
| 3,857 | 17,519 | 1,275 | 5,720 | 2,149 | - | - | - | - |
| 4,286 | 15,048 | -0,243 | 7,781 | 2,923 | - | - | - | - |
| 4,714 | 11,705 | -2,088 | 9,838 | 3,696 | - | - | - | - |
| 5,143 | 7,475 | -4,267 | 11,899 | 4,470 | - | - | - | - |
| 5,571 | 2,378 | -6,771 | 13,956 | 5,243 | - | - | - | - |
| 6,000 | -3,611L | -9,611L | 16,018L | 6,018L | 25,628 | 9,628 | - | - |
| 6,000 | -3,611R | -9,611R | -3,611R | -9,611R | - | - | - | - |
| 6,250 | -2,765 | -7,360 | -3,159 | -8,409 | - | - | - | - |
| 6,500 | -2,032 | -5,409 | -2,708 | -7,208 | - | - | - | - |
| 6,750 | -1,411 | -3,756 | -2,257 | -6,007 | - | - | - | - |
| 7,000 | -0,903 | -2,403 | -1,805 | -4,805 | - | - | - | - |
| 7,250 | -0,508 | -1,353 | -1,354 | -3,604 | - | - | - | - |
| 7,500 | -0,227 | -0,603 | -0,903 | -2,403 | - | - | - | - |
| 7,750 | -0,057 | -0,152 | -0,451 | -1,201 | - | - | - | - |
| 8,000 | 0,000 | 0,000 | 0,000 | 0,000 | - | - | - | - |



| Envelope characteristic (SLS) | | | | | | | | |
|-------------------------------|--------------------------|--------------------------|-------------------------|-------------------------|-------------------------|-------------------------|---------------------------|---------------------------|
| x [m] | Max M ₂ [kNm] | Min M ₂ [kNm] | Max V ₃ [kN] | Min V ₃ [kN] | Max R _z [kN] | Min R _z [kN] | Max RO _x [kNm] | Min RO _x [kNm] |
| 0,000 | 0,000 | 0,000 | -2,899 | -9,566 | 9,566 | 2,899 | - | - |
| 0,429 | 3,788 | 1,117 | -2,326 | -8,134 | - | - | - | - |
| 0,857 | 6,959 | 1,988 | -1,753 | -6,706 | - | - | - | - |
| 1,286 | 9,526 | 2,616 | -1,180 | -5,274 | - | - | - | - |
| 1,714 | 11,478 | 2,999 | -0,607 | -3,846 | - | - | - | - |
| 2,143 | 12,823 | 3,137 | -0,034 | -2,414 | - | - | - | - |
| 2,571 | 13,556 | 3,031 | 0,539 | -0,986 | - | - | - | - |
| 3,000 | 13,680 | 2,680 | 1,112 | 0,446 | - | - | - | - |
| 3,429 | 13,174 | 2,077 | 2,544 | 1,019 | - | - | - | - |
| 3,857 | 12,059 | 1,230 | 3,972 | 1,592 | - | - | - | - |
| 4,286 | 10,331 | 0,137 | 5,404 | 2,165 | - | - | - | - |
| 4,714 | 7,998 | -1,197 | 6,832 | 2,738 | - | - | - | - |
| 5,143 | 5,048 | -2,780 | 8,264 | 3,311 | - | - | - | - |
| 5,571 | 1,496 | -4,603 | 9,692 | 3,884 | - | - | - | - |
| 6,000 | -2,674L | -6,674L | 11,124L | 4,457L | 17,799 | 7,132 | - | - |
| 6,000 | -2,674R | -6,674R | -2,674R | -6,674R | - | - | - | - |
| 6,250 | -2,048 | -5,112 | -2,340 | -5,840 | - | - | - | - |
| 6,500 | -1,505 | -3,756 | -2,006 | -5,006 | - | - | - | - |
| 6,750 | -1,045 | -2,609 | -1,672 | -4,172 | - | - | - | - |
| 7,000 | -0,669 | -1,669 | -1,337 | -3,337 | - | - | - | - |
| 7,250 | -0,377 | -0,940 | -1,003 | -2,503 | - | - | - | - |
| 7,500 | -0,168 | -0,419 | -0,669 | -1,669 | - | - | - | - |
| 7,750 | -0,042 | -0,106 | -0,334 | -0,834 | - | - | - | - |
| 8,000 | 0,000 | 0,000 | 0,000 | 0,000 | - | - | - | - |



Reactions extremes

| Reactions extremes basic design (ULS) | |
|---------------------------------------|--|
| x [m] | Reaction |
| 0,000 | Max $R_z = 13,814\text{kN}$ - Q4:G1+G2 |
| 0,000 | Min $R_z = 3,814\text{kN}$ - Q5:G1+G2 |
| 6,000 | Max $R_z = 25,628\text{kN}$ - Q3:G1+G2 |
| 6,000 | Min $R_z = 9,628\text{kN}$ - G1+G2 |

| Reactions extremes characteristic (SLS) | |
|---|--|
| x [m] | Reaction |
| 0,000 | Max $R_z = 9,566\text{kN}$ - Q4:G1+G2 |
| 0,000 | Min $R_z = 2,899\text{kN}$ - Q5:G1+G2 |
| 6,000 | Max $R_z = 17,799\text{kN}$ - Q3:G1+G2 |
| 6,000 | Min $R_z = 7,132\text{kN}$ - G1+G2 |

Lateral-torsional buckling

Lat. tors. buckling due to b. moment M_y :

| Sector no. | Start [m] | End [m] | I_{z1} [m] | Moment area shape | Load position |
|------------|-----------|---------|--------------|---|---------------|
| 1 | 0,000 | 8,000 | 8,000 | Simple supported beam, distributed load | 1,000 |

Lat. tors. buckling due to b. moment M_z :

| Sector no. | Start [m] | End [m] | I_{y1} [m] | Moment area shape | Load position |
|------------|-----------|---------|--------------|-------------------|---------------|
| 1 | 0,000 | 8,000 | No input | No input | - |

1.2 Results

Intermediate results

Cross-section classification:

$$\varepsilon = \sqrt{(235,0 / f_y)} = \sqrt{(235,0 / 235,0)} = 1,000$$

Web classification:

$$c = 92,0 \text{ mm}$$

$$t = 7,0 \text{ mm}$$

$$c/t = 13,1; \quad 13,1 \leq 33,0; \quad \text{Class 1}$$

Top flange left part classification:

$$c = 54,5 \text{ mm}$$

$$t = 12,0 \text{ mm}$$

$$c/t = 4,5; \quad 4,5 \leq 9,0; \quad \text{Class 1}$$

Top flange right part classification:

$$c = 54,5 \text{ mm}$$

$$t = 12,0 \text{ mm}$$

$$c/t = 4,5; \quad 4,5 \leq 9,0; \quad \text{Class 1}$$

Bottom flange left part classification:

$$c = 54,5 \text{ mm}$$

$$t = 12,0 \text{ mm}$$

$$c/t = 4,5; \quad 4,5 \leq 9,0; \quad \text{Class 1}$$

Bottom flange right part classification:

$$c = 54,5 \text{ mm}$$

$$t = 12,0 \text{ mm}$$

$$c/t = 4,5; \quad 4,5 \leq 9,0; \quad \text{Class 1}$$

Cross-section class 1

Calculation of shear res. in z-axis direction

$$\text{Shear area } A_{V,z} = 1,308E03 \text{ mm}^2$$

$$\text{Cross-section shear resistance } V_{pl,Rd,z} = 177,466 \text{ kN}$$

Shear buckling resistance:

$$d/t_w = 13,1 < 69,0$$

Web buckling has not to be checked

$$\text{Shear buckling resistance } V_{ba,Rd,z} = 177,466 \text{ kN}$$

$$\text{Design shear resistance } V_{Rd,z} = 177,466 \text{ kN}$$

Calculation of shear res. in y-axis direction

$$\text{Shear area } A_{V,y} = 2,988E03 \text{ mm}^2$$

$$\text{Cross-section shear resistance } V_{pl,Rd,y} = 405,404 \text{ kN}$$

B. moment M_y resistance calculation

$$V_z \leq 0,5 * 177,466 \text{ kN} \Rightarrow \text{"inconsiderable shear"} \text{ for z axis}$$

$$V_y \leq 0,5 * 405,404 \text{ kN} \Rightarrow \text{"inconsiderable shear"} \text{ for y axis}$$

$$\text{Plastic section modulus } W_{pl,y} = 2,454E05 \text{ mm}^3$$

$$\text{Cross-section b. moment resistance } M_{c,Rd,y} = 57,669 \text{ kNm}$$

$$\text{Design b. moment resistance } M_{c,Rd,y} = 57,669 \text{ kNm}$$

Buckling effect calculation:

$$\text{Laterally restrained point spacing } L_{z1} = 8,000 \text{ m}$$

$$\text{Cross-section load position } z_p = 140,0 \text{ mm}$$

$$\text{Buckling length factors: } k = 1,000; \quad k_w = 1,000$$

$$z_g = 70,0 \text{ mm}$$

$$z_j = 0,0 \text{ mm}$$

$$\text{Dimensionless torsion parameter: } \kappa_{wt} = 0,212$$

$$\text{Dimensionless parameter of load application point with respect to shear centre : } \zeta_g = 0,232$$

$$\text{Dimensionless cross-section asymmetry parameter: } \zeta_j = 0,000$$

$$\text{Cross-section asymmetry parameter: } \psi_f = 0,000$$

Load & support condition factors:

$$C_1 = 1,130; \quad C_2 = 0,460; \quad C_3 = 0,530$$

$$\text{Dimensionless critical bending moment: } \mu_{cr} = 1,041$$

$$\text{El. crit. bending moment } M_{cr} = 55,980 \text{ kNm}$$

$$\text{Rel. slenderness } \lambda_{bar,LT} = 1,015$$

Reduction factor determination $\chi_{LT,y}$ from buckling curve a:

$$\text{Imperfection factor } \alpha = 0,210$$

$$\varphi = 1,101$$

Transverse and torsion stability factor $\chi_{LT,y} = 0,655$

Buckling b. moment resistance $M_{b,Rd,y} = 37,781 \text{ kNm}$

B. moment M_z resistance calculation

$V_z \leq 0.5 * 177,466 \text{ kN} \Rightarrow$ "inconsiderable shear" for z axis

$V_y \leq 0.5 * 405,404 \text{ kN} \Rightarrow$ "inconsiderable shear" for y axis

Plastic section modulus $W_{pl,z} = 1,198E05 \text{ mm}^3$

Cross-section b. moment resistance $M_{c,Rd,z} = 28,153 \text{ kNm}$

Design b. moment resistance $M_{c,Rd,z} = 28,153 \text{ kNm}$

Shear capacity check

| Magnitude | Loading | Resistance | Utilization | |
|-----------|----------|------------|-------------|------|
| V_z | 0,602 kN | 177,466 kN | 0,3 % | Pass |

Bending moment check

$0,167 < 1 \Rightarrow$ Pass

Cross-section classification:

$$\varepsilon = \sqrt{(235,0 / f_y)} = \sqrt{(235,0 / 235,0)} = 1,000$$

Web classification:

$$c = 92,0 \text{ mm}$$

$$t = 7,0 \text{ mm}$$

$$c/t = 13,1; \quad 13,1 \leq 33,0; \quad \text{Class 1}$$

Top flange left part classification:

$$c = 54,5 \text{ mm}$$

$$t = 12,0 \text{ mm}$$

$$c/t = 4,5; \quad 4,5 \leq 9,0; \quad \text{Class 1}$$

Top flange right part classification:

$$c = 54,5 \text{ mm}$$

$$t = 12,0 \text{ mm}$$

$$c/t = 4,5; \quad 4,5 \leq 9,0; \quad \text{Class 1}$$

Bottom flange left part classification:

$$c = 54,5 \text{ mm}$$

$$t = 12,0 \text{ mm}$$

$$c/t = 4,5; \quad 4,5 \leq 9,0; \quad \text{Class 1}$$

Bottom flange right part classification:

$$c = 54,5 \text{ mm}$$

$$t = 12,0 \text{ mm}$$

$$c/t = 4,5; \quad 4,5 \leq 9,0; \quad \text{Class 1}$$

Cross-section class 1

Calculation of shear res. in z-axis direction

Shear area $A_{v,z} = 1,308E03 \text{ mm}^2$

Cross-section shear resistance $V_{pl,Rd,z} = 177,466 \text{ kN}$

Shear buckling resistance:

$$d/t_w = 13,1 < 69,0$$

Web buckling has not to be checked

Shear buckling resistance $V_{ba,Rd,z} = 177,466 \text{ kN}$

Design shear resistance $V_{Rd,z} = 177,466 \text{ kN}$

Calculation of shear res. in y-axis direction

Shear area $A_{v,y} = 2,988E03 \text{ mm}^2$

Cross-section shear resistance $V_{pl,Rd,y} = 405,404 \text{ kN}$

B. moment M_y resistance calculation

$V_z \leq 0.5 * 177,466 \text{ kN} \Rightarrow$ "inconsiderable shear" for z axis
 $V_y \leq 0.5 * 405,404 \text{ kN} \Rightarrow$ "inconsiderable shear" for y axis
 Plastic section modulus $W_{pl,y} = 2,454E05 \text{ mm}^3$
 Cross-section b. moment resistance $M_{c,Rd,y} = 57,669 \text{ kNm}$
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 Buckling effect calculation:
 Laterally restrained point spacing $L_{z1} = 8,000 \text{ m}$
 Cross-section load position $z_p = 140,0 \text{ mm}$
 Buckling length factors: $k = 1,000$; $k_w = 1,000$
 $z_g = 70,0 \text{ mm}$
 $z_j = 0,0 \text{ mm}$
 Dimensionless torsion parameter: $\kappa_{wt} = 0,212$
 Dimensionless parameter of load application point with respect to shear centre : $\zeta_g = 0,232$
 Dimensionless cross-section asymmetry parameter: $\zeta_j = 0,000$
 Cross-section asymmetry parameter: $\psi_f = 0,000$
 Load & support condition factors:
 $C_1 = 1,130$; $C_2 = 0,460$; $C_3 = 0,530$
 Dimensionless critical bending moment: $\mu_{cr} = 1,041$
 El. crit. bending moment $M_{cr} = 55,980 \text{ kNm}$
 Rel. slenderness $\lambda_{bar,LT} = 1,015$
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 $\varphi = 1,101$
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B. moment M_z resistance calculation

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 Plastic section modulus $W_{pl,z} = 1,198E05 \text{ mm}^3$
 Cross-section b. moment resistance $M_{c,Rd,z} = 28,153 \text{ kNm}$
 Design b. moment resistance $M_{c,Rd,z} = 28,153 \text{ kNm}$

Shear capacity check

| Magnitude | Loading | Resistance | Utilization | |
|-----------|----------|------------|-------------|------|
| V_z | 1,602 kN | 177,466 kN | 0,9 % | Pass |

Bending moment check

$0,088 < 1 \Rightarrow$ Pass

Cross-section classification:

$\varepsilon = \sqrt{(235,0 / f_y)} = \sqrt{(235,0 / 235,0)} = 1,000$

Web classification:

$c = 92,0 \text{ mm}$

$t = 7,0 \text{ mm}$

$c/t = 13,1$; $13,1 \leq 33,0$; Class 1

Top flange left part classification:

$c = 54,5 \text{ mm}$

$t = 12,0 \text{ mm}$

$c/t = 4,5$; $4,5 \leq 9,0$; Class 1

Top flange right part classification:

$c = 54,5 \text{ mm}$

$t = 12,0 \text{ mm}$

$c/t = 4,5$; $4,5 \leq 9,0$; Class 1

Bottom flange left part classification:

$$c = 54,5 \text{ mm}$$

$$t = 12,0 \text{ mm}$$

$$c/t = 4,5; \quad 4,5 \leq 9,0; \quad \text{Class 1}$$

Bottom flange right part classification:

$$c = 54,5 \text{ mm}$$

$$t = 12,0 \text{ mm}$$

$$c/t = 4,5; \quad 4,5 \leq 9,0; \quad \text{Class 1}$$

Cross-section class 1

Calculation of shear res. in z-axis direction

$$\text{Shear area } A_{v,z} = 1,308E03 \text{ mm}^2$$

$$\text{Cross-section shear resistance } V_{pl,Rd,z} = 177,466 \text{ kN}$$

Shear buckling resistance:

$$d/t_w = 13,1 < 69,0$$

Web buckling has not to be checked

$$\text{Shear buckling resistance } V_{ba,Rd,z} = 177,466 \text{ kN}$$

$$\text{Design shear resistance } V_{Rd,z} = 177,466 \text{ kN}$$

Calculation of shear res. in y-axis direction

$$\text{Shear area } A_{v,y} = 2,988E03 \text{ mm}^2$$

$$\text{Cross-section shear resistance } V_{pl,Rd,y} = 405,404 \text{ kN}$$

B. moment M_y resistance calculation

$$V_z \leq 0,5 * 177,466 \text{ kN} \Rightarrow \text{"inconsiderable shear"} \text{ for z axis}$$

$$V_y \leq 0,5 * 405,404 \text{ kN} \Rightarrow \text{"inconsiderable shear"} \text{ for y axis}$$

$$\text{Plastic section modulus } W_{pl,y} = 2,454E05 \text{ mm}^3$$

$$\text{Cross-section b. moment resistance } M_{c,Rd,y} = 57,669 \text{ kNm}$$

$$\text{Design b. moment resistance } M_{c,Rd,y} = 57,669 \text{ kNm}$$

Buckling effect calculation:

$$\text{Laterally restrained point spacing } L_{z1} = 8,000 \text{ m}$$

$$\text{Cross-section load position } z_p = 140,0 \text{ mm}$$

$$\text{Buckling length factors: } k = 1,000; \quad k_w = 1,000$$

$$z_g = 70,0 \text{ mm}$$

$$z_j = 0,0 \text{ mm}$$

$$\text{Dimensionless torsion parameter: } \kappa_{wt} = 0,212$$

$$\text{Dimensionless parameter of load application point with respect to shear centre : } \zeta_g = 0,232$$

$$\text{Dimensionless cross-section asymmetry parameter: } \zeta_j = 0,000$$

$$\text{Cross-section asymmetry parameter: } \psi_f = 0,000$$

Load & support condition factors:

$$C_1 = 1,130; \quad C_2 = 0,460; \quad C_3 = 0,530$$

$$\text{Dimensionless critical bending moment: } \mu_{cr} = 1,041$$

$$\text{El. crit. bending moment } M_{cr} = 55,980 \text{ kNm}$$

$$\text{Rel. slenderness } \lambda_{bar,LT} = 1,015$$

Reduction factor determination $\chi_{LT,y}$ from buckling curve a:

$$\text{Imperfection factor } \alpha = 0,210$$

$$\varphi = 1,101$$

$$\text{Transverse and torsion stability factor } \chi_{LT,y} = 0,655$$

$$\text{Buckling b. moment resistance } M_{b,Rd,y} = 37,781 \text{ kNm}$$

B. moment M_z resistance calculation

$$V_z \leq 0,5 * 177,466 \text{ kN} \Rightarrow \text{"inconsiderable shear"} \text{ for z axis}$$

$$V_y \leq 0,5 * 405,404 \text{ kN} \Rightarrow \text{"inconsiderable shear"} \text{ for y axis}$$

$$\text{Plastic section modulus } W_{pl,z} = 1,198E05 \text{ mm}^3$$

Cross-section b. moment resistance $M_{c,Rd,z} = 28,153 \text{ kNm}$
 Design b. moment resistance $M_{c,Rd,z} = 28,153 \text{ kNm}$

Shear capacity check

| Magnitude | Loading | Resistance | Utilization | |
|-----------|----------|------------|-------------|------|
| V_z | 0,602 kN | 177,466 kN | 0,3 % | Pass |

Bending moment check

$0,525 < 1 \Rightarrow$ Pass

Cross-section classification:

$$\varepsilon = \sqrt{(235,0 / f_y)} = \sqrt{(235,0 / 235,0)} = 1,000$$

Web classification:

$$c = 92,0 \text{ mm}$$

$$t = 7,0 \text{ mm}$$

$$c/t = 13,1; \quad 13,1 \leq 33,0; \quad \text{Class 1}$$

Top flange left part classification:

$$c = 54,5 \text{ mm}$$

$$t = 12,0 \text{ mm}$$

$$c/t = 4,5; \quad 4,5 \leq 9,0; \quad \text{Class 1}$$

Top flange right part classification:

$$c = 54,5 \text{ mm}$$

$$t = 12,0 \text{ mm}$$

$$c/t = 4,5; \quad 4,5 \leq 9,0; \quad \text{Class 1}$$

Bottom flange left part classification:

$$c = 54,5 \text{ mm}$$

$$t = 12,0 \text{ mm}$$

$$c/t = 4,5; \quad 4,5 \leq 9,0; \quad \text{Class 1}$$

Bottom flange right part classification:

$$c = 54,5 \text{ mm}$$

$$t = 12,0 \text{ mm}$$

$$c/t = 4,5; \quad 4,5 \leq 9,0; \quad \text{Class 1}$$

Cross-section class 1

Calculation of shear res. in z-axis direction

Shear area $A_{v,z} = 1,308E03 \text{ mm}^2$

Cross-section shear resistance $V_{pl,Rd,z} = 177,466 \text{ kN}$

Shear buckling resistance:

$$d/t_w = 13,1 < 69,0$$

Web buckling has not to be checked

Shear buckling resistance $V_{ba,Rd,z} = 177,466 \text{ kN}$

Design shear resistance $V_{Rd,z} = 177,466 \text{ kN}$

Calculation of shear res. in y-axis direction

Shear area $A_{v,y} = 2,988E03 \text{ mm}^2$

Cross-section shear resistance $V_{pl,Rd,y} = 405,404 \text{ kN}$

B. moment M_y resistance calculation

$V_z \leq 0,5 * 177,466 \text{ kN} \Rightarrow$ "inconsiderable shear" for z axis

$V_y \leq 0,5 * 405,404 \text{ kN} \Rightarrow$ "inconsiderable shear" for y axis

Plastic section modulus $W_{pl,y} = 2,454E05 \text{ mm}^3$

Cross-section b. moment resistance $M_{c,Rd,y} = 57,669 \text{ kNm}$

Design b. moment resistance $M_{c,Rd,y} = 57,669 \text{ kNm}$

Buckling effect calculation:

Laterally restrained point spacing $L_{z1} = 8,000 \text{ m}$

Cross-section load position $z_p = 140,0 \text{ mm}$

Buckling length factors: $k = 1,000$; $k_w = 1,000$

$z_g = 70,0$ mm

$z_j = 0,0$ mm

Dimensionless torsion parameter: $\kappa_{wt} = 0,212$

Dimensionless parameter of load application point with respect to shear centre : $\zeta_g = 0,232$

Dimensionless cross-section asymmetry parameter: $\zeta_j = 0,000$

Cross-section asymmetry parameter: $\psi_f = 0,000$

Load & support condition factors:

$C_1 = 1,130$; $C_2 = 0,460$; $C_3 = 0,530$

Dimensionless critical bending moment: $\mu_{cr} = 1,041$

El. crit. bending moment $M_{cr} = 55,980$ kNm

Rel. slenderness $\lambda_{bar,LT} = 1,015$

Reduction factor determination $\chi_{LT,y}$ from buckling curve a:

Imperfection factor $\alpha = 0,210$

$\varphi = 1,101$

Transverse and torsion stability factor $\chi_{LT,y} = 0,655$

Buckling b. moment resistance $M_{b,Rd,y} = 37,781$ kNm

B. moment M_z resistance calculation

$V_z \leq 0.5 * 177,466$ kN \Rightarrow "inconsiderable shear" for z axis

$V_y \leq 0.5 * 405,404$ kN \Rightarrow "inconsiderable shear" for y axis

Plastic section modulus $W_{pl,z} = 1,198E05$ mm³

Cross-section b. moment resistance $M_{c,Rd,z} = 28,153$ kNm

Design b. moment resistance $M_{c,Rd,z} = 28,153$ kNm

Shear capacity check

| Magnitude | Loading | Resistance | Utilization | |
|-----------|----------|------------|-------------|------|
| V_z | 1,602 kN | 177,466 kN | 0,9 % | Pass |

Bending moment check

$0,445 < 1 \Rightarrow$ Pass

Overall check

Decisive load: Q4:G1+G2; **Cross-section class:** 1

Check of shear due to shear force V_z :

$0,602$ kN $< 177,466$ kN **Pass**

Bending moment: $M_y = 19,818$ kNm

Bending moment check:

Resistance: $M_{y,R} = 37,781$ kNm

$|0,525| < 1$ **Pass**

Section ok

Deflection

Characteristic load states

Maximum deformation is 14,7mm at point $x = 8,000$ m

Maximum allowed deformation is $4,000$ m / $250,0 = 16,0$ mm

$14,7$ mm $< 16,0$ mm \square **Pass**

Member deflection PASS

