

1. input data

1.1. general information

verifications of stability acc. to EN 1993-1-1

c/t-verification (classification of cross-section)

lateral torsional buckling with the method of fictitious bars for N+My, interaction proof only with eqn. (6.61)

1.2. safety factor of material

resistance of cross-sections $\gamma_{M0} = 1.00$

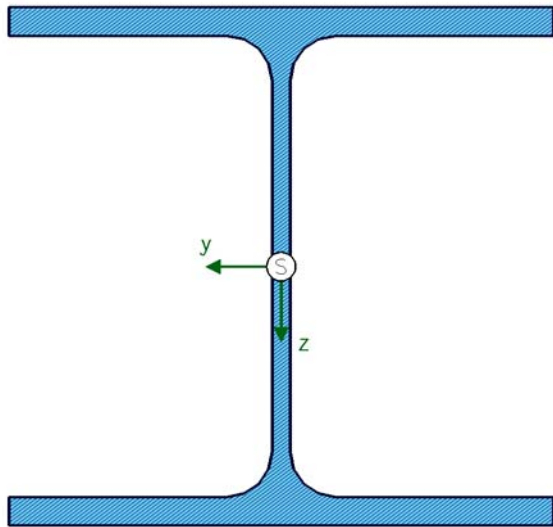
resistance of members in stability failure $\gamma_{M1} = 1.10$

1.3. cross-section

material: S235 (St37) ($E = 210000 \text{ N/mm}^2$, $G = 80769 \text{ N/mm}^2$, $f_{y,k} = 235 \text{ N/mm}^2$)

section: HE180A

section scale 1:2.5



1.4. cross-section values (related to the centre of gravity S)

$I_y = 2510.0 \text{ cm}^4$, $I_z = 925.0 \text{ cm}^4$, $I_{yz} = 2510.0 \text{ cm}^4$, $I_{\eta} = 925.0 \text{ cm}^4$, $\alpha = 0.0^\circ$

$I_{\omega} = 60210.0 \text{ cm}^6$, $I_T = 14.9 \text{ cm}^4$

$W_y = 294.0 \text{ cm}^3$, $W_z = 103.0 \text{ cm}^3$, $W_{pl,y} = 325.0 \text{ cm}^3$, $W_{pl,z} = 157.0 \text{ cm}^3$

$z_{m,y} = 0.0 \text{ mm}$, $z_{m,z} = 0.0 \text{ mm}$, $A = 45.3 \text{ cm}^2$, cross-section is torsionally rigid

1.5. load application point (related to the center of the surrounding rectangle)

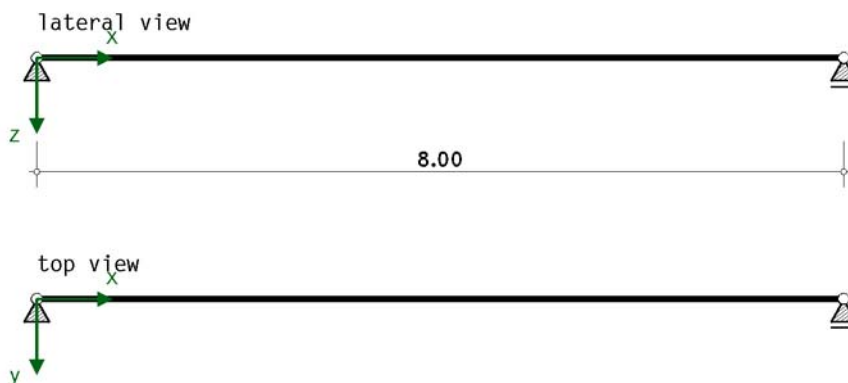
$y_{load} = 0.0 \text{ mm}$ (centroid)

$z_{load} = 0.0 \text{ mm}$ (centroid)

1.6. static system

all bearings with fork restraint, bar length 8.000 [m]

no intermediate bearing in z-direction, no intermediate bearing in y-direction



1.7. buckling coefficients

⊥ y-axis: $\beta_y = 1.000$, ⊥ z-axis: $\beta_z = 1.000$

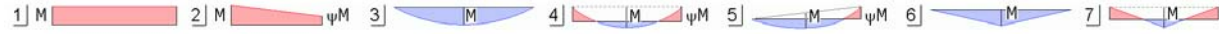
warping restraint intensity $\beta_0 = 1.000$

1.8. design member forces (load combinations)

Lk	N _d kN	t _{type} -y-	M _{0y,d} kNm	ψ _y -	k _{c,y} -	ζ _y -
1	105.00	3	32.00	0.000	0.940	1.128

N_d: constant axial force in the bar; type (y): type of moment curves each direction; M_{0y,d}, ψ_y: reference values of moment curve
k_{c,y}, ζ_y: coefficients for calculation

types of moment curves



1.9. torsionally elastic bedding with free specification of torsional spring and shear field stiffness

shear field stiffness

required shear field stiffness of each beam req $S_i = (E \cdot I_{\omega} \cdot \pi^2 / L^2 + G \cdot I_T + E \cdot I_{zl} \cdot \pi^2 / L^2 \cdot h^2 / 4) \cdot 70 / h^2 = 38719.7 \text{ kN}$

with $h = 171.0 \text{ mm}$, $L = 8.000 \text{ m}$, $I_{\omega} = 60210.00 \text{ cm}^6$, $I_T = 14.90 \text{ cm}^4$, $I_z = 925.00 \text{ cm}^4$

torsionally elastic bedding

$C_D = 100.000 \text{ kNm/m}$ (user-defined) $\Rightarrow I_T^* = 817.75 \text{ cm}^4$

$I_T^* = I_T + \Delta I_T$ with $I_T = 14.90 \text{ cm}^4$, $\Delta I_T = (C_D \cdot c^2) / (G \cdot \pi^2) = 802.85 \text{ cm}^4$, $C_D = 100.000 \text{ kNm/m}$, $c = 8.000 \text{ m}$

2. verifications

2.1. classification of cross-section

2.1.1. load combination 1 $\Rightarrow$ section class 1

no	c mm	t mm	c/t -	ε -	σ ₁ N/mm ²	σ ₂ N/mm ²	tab 5.2	α -	ψ -	k _σ -	class -
1	72.0	9.5	7.58	1.000	126.13	126.13	single 1/1	---	---	---	1
2	72.0	9.5	7.58	1.000	126.13	126.13	single 1/1	---	---	---	1
3	122.0	6.0	20.33	1.000	100.95	-54.59	both 3/1	0.805	---	---	1
4	72.0	9.5	7.58	1.000	-79.77	-79.77	-----	---	---	---	---
5	72.0	9.5	7.58	1.000	-79.77	-79.77	-----	---	---	---	---

compressive stresses have a positive sign acc. to EC 3.

verifications are carried out in the **specified** cross-section class 1: $U_{eff} = 0.842 < 1$ **ok**

2.2. lateral torsional buckling

2.2.1. flexural buckling for normal force

$I_p = 3435 \text{ cm}^4$, $I_T = 818 \text{ cm}^4$, $i_p^2 = 7583 \text{ mm}^2$, $c^2 = 2211392 \text{ mm}^2$, $i_m^2 = 7583 \text{ mm}^2$

flexural buckling around y-axis:

$i_y = 74.4 \text{ mm}$, $\beta_z = 1.00$ (⊥ z-axis), $L_{cr,z} = 8.000 \text{ m}$, $\lambda_1 = 93.913$

$\lambda_y = 1.144$, y-buckling curve b $\Rightarrow \alpha_y = 0.34$, $\Phi_y = 1.315$, $\chi_y = 0.509$, **N_{by,Rd} = 492.79 kN**

flexural buckling around z-axis:

$i_z = 45.2 \text{ mm}$, $\beta_y = 1.00$ (⊥ y-axis), $L_{cr,y} = 8.000 \text{ m}$, $\lambda_1 = 93.913$

$\lambda_z = 1.885$, z-buckling curve c $\Rightarrow \alpha_z = 0.49$, $\Phi_z = 2.690$, $\chi_z = 0.217$, **N_{bz,Rd} = 210.01 kN**

2.2.1.1. utilisations

Lk	N _d kN	U _y -	U _z -
1	105.00	0.213	0.500

2.2.2. lateral torsional buckling for bending around y-axis

$c^2 = 2211392 \text{ mm}^2$, buckling curve b $\Rightarrow \alpha_{LT} = 0.34$, **N_{cr} = 299.56 kN**

2.2.2.1. utilisations

Lk	M _{cr} kNm	λ _{LT} -	f -	Φ _{LT} -	χ _{LT} m	χ _{LT,mod} m	M _{Ed} kNm	M _{b,Rd} kNm	U -
1	502.51	0.390	0.980	0.555	1.000	1.000	32.00	69.43	0.461

2.2.3. interaction

Lk	eqn.	C _{my} -	k _{yy} -	C _{mLT} -	k _{zy} -	U -
1	(6.61)	0.950	1.112	0.950	---	0.726
	(6.62)	---	---	0.950	0.667	0.807

max U = 0.807 < 1 **ok**

3. final result

maximum utilisation $U = 0.807 < 1$ **ok**
c/t-utilisation $U = 0.842 < 1$ **ok**

verification succeeded