

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 $\gamma_{M0} = 1.00$

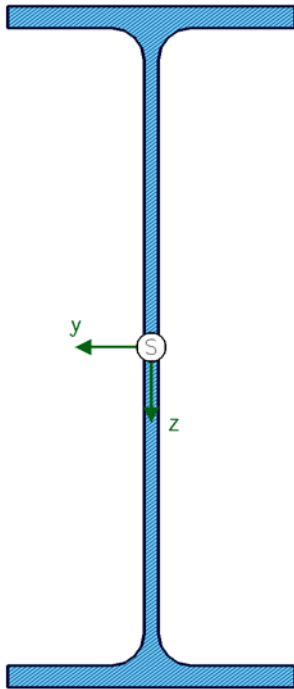
resistance of members in stability failure $\gamma_{M1} = 1.10$

1.3. cross-section

material: S355 (St52) ($E = 210000 \text{ N/mm}^2$, $G = 80769 \text{ N/mm}^2$, $f_{y,k} = 355 \text{ N/mm}^2$)

section: IPE450

section scale 1:5.0



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

$I_y = 33740.0 \text{ cm}^4$, $I_z = 1680.0 \text{ cm}^4$, $I_{\omega} = 33740.0 \text{ cm}^4$, $I_{\eta} = 1680.0 \text{ cm}^4$, $\alpha = 0.0^\circ$

$I_{\omega} = 791000.0 \text{ cm}^6$, $I_T = 67.1 \text{ cm}^4$

$W_y = 1500.0 \text{ cm}^3$, $W_z = 176.0 \text{ cm}^3$, $W_{pl,y} = 1702.0 \text{ cm}^3$, $W_{pl,z} = 275.0 \text{ cm}^3$

$z_{m,y} = 0.0 \text{ mm}$, $z_{m,z} = 0.0 \text{ mm}$, $A = 98.8 \text{ cm}^2$, cross-section is torsionally soft

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

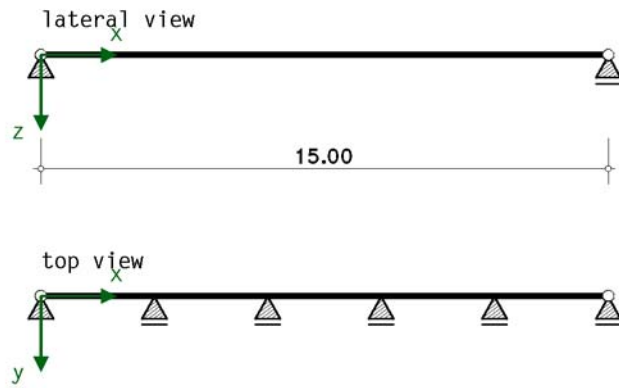
$y_{load} = 0.0 \text{ mm}$ (centroid)

$z_{load} = -225.0 \text{ mm}$ (upper edge of cross-section)

1.6. static system

all bearings with fork restraint, bar length 15.000 [m]

no intermediate bearing in z-direction, 4 intermediate bearing in y-direction



1.7. buckling coefficients

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

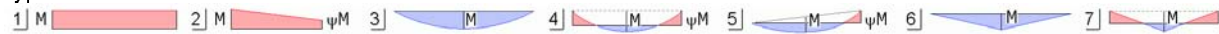
warping restraint intensity $\beta_0 = 1.000$

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	24.00	5	393.80	0.798	0.910	1.993

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 induced by 4 cross beams

section IPE180

h = 180.0 mm, t_w = 5.3 mm, b_f = 91.0 mm, t_f = 8.0 mm, r = 9.0 mm

A = 23.95 cm², I_y = 1316.94 cm⁴, I_z = 100.83 cm⁴, I_T = 5.15 cm⁴, y_s = -45.5 mm, z_s = 90.0 mm

E = 210000 N/mm², c = 3.000 m (distance), I_y/c = 4389797 mm³, s = 6.000 m (support width)

C_{D,B}: calculation acc. to Lindner, C_{D,c}: inner field

C_{D,B} = 26.620 kNm/m, C_{D,c} = 614.572 kNm/m, C_D = 25.515 kNm/m ⇒ I_T^{*} = 95.91 cm⁴

I_T^{*} = I_T + ΔI_T with I_T = 67.10 cm⁴, ΔI_T = (C_D · c²) / (G · π²) = 28.81 cm⁴, C_D = 25.515 kNm/m, c = 3.000 m

2. verifications

2.1. classification of cross-section

2.1.1. load combination 1 ⇒ 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	69.3	14.6	4.75	0.814	205.19	205.19	single 1/1	---	---	---	1
2	69.3	14.6	4.75	0.814	205.19	205.19	single 1/1	---	---	---	1
3	378.8	9.4	40.30	0.814	178.84	-173.98	both 3/1	0.509	---	---	1
4	69.3	14.6	4.75	0.814	-200.34	-200.34	-----	---	---	---	---
5	69.3	14.6	4.75	0.814	-200.34	-200.34	-----	---	---	---	---

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

verifications are carried out in the **specified** cross-section class 2: $U_{eff} = 0.611 < 1$ **ok**

2.2. lateral torsional buckling

2.2.1. flexural buckling for normal force

I_p = 35420 cm⁴, I_T = 96 cm⁴, i_p² = 35850 mm², c² = 67105 mm², i_m² = 35850 mm²

flexural buckling around y-axis:

i_y = 184.8 mm, β_z = 1.00 (⊥ z-axis), L_{cr,z} = 3.000 m, λ₁ = 76.409

λ_y = 1.062, y-buckling curve a ⇒ α_y = 0.21, Φ_y = 1.155, γ_y = 0.622, N_{by,Rd} = 1983.40 kN

flexural buckling around z-axis:

i_z = 41.2 mm, β_y = 1.00 (⊥ y-axis), L_{cr,y} = 15.000 m, λ₁ = 76.409

λ_z = 0.952, z-buckling curve b ⇒ α_z = 0.34, Φ_z = 1.081, γ_z = 0.628, N_{bz,Rd} = 2001.21 kN

2.2.1.1. utilisations

Lk	N _d kN	U _y -	U _z -
1	24.00	0.012	0.012

2.2.2. lateral torsional buckling for bending around y-axis

$c^2 = 67105 \text{ mm}^2$, buckling curve c $\Rightarrow \alpha_{LT} = 0.49$, $N_{cr} = 3868.88 \text{ kN}$

2.2.2.1. utilisations

Lk	M _{cr} kNm	λ_{LT} -	f -	Φ_{LT} -	χ_{LT} m	$\chi_{LT,mod}$ m	M _{Ed} kNm	M _{b,Rd} kNm	U -
1	835.08	0.851	0.955	0.882	0.732	0.766	314.25	420.87	0.747

2.2.3. interaction

Lk	eqn.	C _{my} -	k _{yy} -	C _{mLT} -	k _{zy} -	U -
1	(6.61)	0.400	0.404	0.950	---	0.314
	(6.62)	---	---	0.950	0.998	0.757

max U = 0.757 < 1 **ok**

3. final result

maximum utilisation U = 0.757 < 1 **ok**

c/t-utilisation U = 0.611 < 1 **ok**

verification succeeded