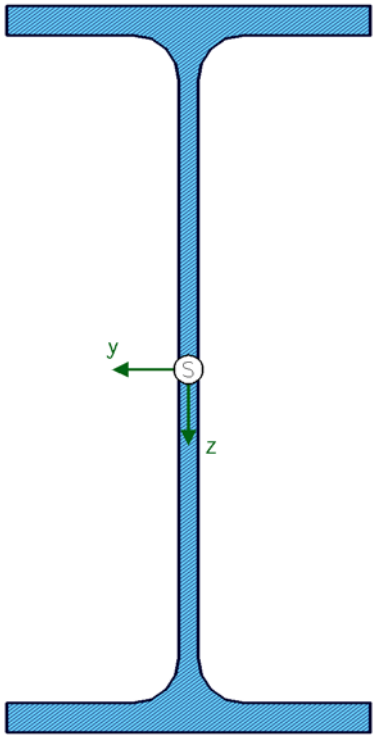
verification of stability EC 3-1-2 (12.10), NA: Deutschland 4H-EC3ST version: 12/2021-1b

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 My

1.2. safety factor of material
resistance of cross-sections γ_{M0} = 1.00
resistance of members in stability failure γ_{M1} = 1.10

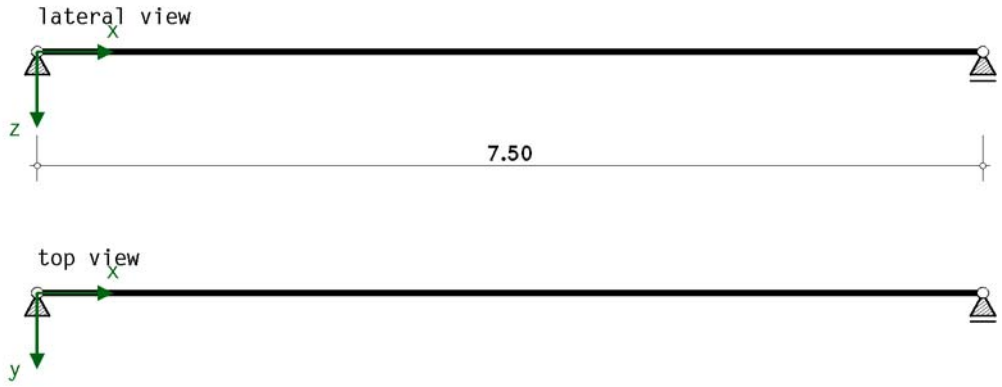
1.3. cross-section
material: S235 (St37) (E = 210000 N/mm^2, G = 80769 N/mm^2, $f_{y,k}$ = 235 N/mm^2)
section: IPE240
section scale 1:2.5



1.4. cross-section values (related to the centre of gravity S)
I_y = 3890.0 cm^4, I_z = 284.0 cm^4, I_ζ = 3890.0 cm^4, I_η = 284.0 cm^4, α = 0.0°
I_ω = 37390.0 cm^6, I_T = 12.9 cm^4
W_y = 324.0 cm^3, W_z = 47.3 cm^3, $W_{pl,y}$ = 367.0 cm^3, $W_{pl,z}$ = 74.0 cm^3
$z_{m,y}$ = 0.0 mm, $z_{m,z}$ = -0.0 mm, A = 39.1 cm^2

1.5. load application point (related to the center of the surrounding rectangle)
y_{load} = 0.0 mm (centroid)
z_{load} = -120.0 mm (upper edge of cross-section)

1.6. static system
all bearings with fork restraint, bar length 7.500 [m]
no intermediate bearing in z-direction, no intermediate bearing in y-direction



1.7. buckling coefficients

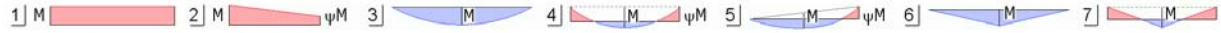
⊥ y-axis: β_y = 1.000, ⊥ z-axis: β_z = 1.000
warping restraint intensity β_0 = 1.000

1.8. design member forces (load combinations)

Lk	type -y-	$M_{0y,d}$ kNm	ψ_y -	$k_{c,y}$ -	ζ_y -
1	5	102.00	0.768	0.910	1.859

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 trapezoidal sheets Hoesch T 35.1, t_{nom} = 1.00 mm

shear field stiffness

ideal shear modulus $G_S = 10^4 / (K_1+K_2/L_S)$ = 24038.5 kN/m
with K_1 = 0.149 m/kN, K_2 = 2.670 m²/kN, L_S = 10.000 m
shear field stiffness $S = G_S \cdot L_S \cdot 0.2$ = 48076.9 kN
shear field stiffness beam $S_i = S/n$ = 8012.8 kN with n = 6
required shear field stiffness of each beam req $S_i = (E \cdot I_\omega \cdot \pi^2/L^2 + G \cdot I_T + E \cdot I_{zl} \cdot \pi^2/L^2 \cdot h^2/4) \cdot 70/h^2$ = 16167.8 kN
with h = 240.0 mm, L = 7.500 m, I_ω = 37390.00 cm⁶, I_T = 12.90 cm⁴, I_z = 284.00 cm⁴
exist S_i = 8012.8 kN < req S_i = 16167.8 kN ⇒ free rotation axis

torsionally elastic bedding

C_{100} = 3.1 kNm/m, $b_{T,max}$ = 40 mm acc. to EC 3-1-3, tab. 10.3 line 2
A = 12.00 kN/m (superimposed load between plate and beam), b_R = 207.0 mm, b_T = 40.0 mm
E = 210000 N/mm², c = 7.500 m (buckling length), I_{eff} = 203000 mm⁴, s = 2.000 m (support width)
$C_{D,B}$: calculation acc. to Wagenknecht, $C_{D,C}$: end field and equidirectional rotation of beams
k_{ba} = 1.440, k_t = 1.372, k_{bR} = 0.894, k_A = 2.045, k_{bT} = 1.000
$C_{D,A}$ = 11.196 kNm/m, $C_{D,B}$ = 54.354 kNm/m, $C_{D,C}$ = 85.260 kNm/m, C_D = 8.372 kNm/m ⇒ **I_T^* = 71.97 cm⁴**
$I_T^* = I_T + \Delta I_T$ with I_T = 12.90 cm⁴, $\Delta I_T = (C_D \cdot c^2)/(G \cdot \pi^2)$ = 59.07 cm⁴, C_D = 8.372 kNm/m, c = 7.500 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/mm²	σ_2 N/mm²	tab 5.2	α -	ψ -	k_σ -	class -
1	41.9	9.8	4.28	1.000	231.79	231.79	single 1/1	---	---	---	1
2	41.9	9.8	4.28	1.000	231.79	231.79	single 1/1	---	---	---	1
3	190.4	6.2	30.71	1.000	191.71	-191.71	both 1/1	---	---	---	1
4	41.9	9.8	4.28	1.000	-231.79	-231.79	---	---	---	---	---
5	41.9	9.8	4.28	1.000	-231.79	-231.79	---	---	---	---	---

compressive stresses have a positive sign acc. to EC 3.
verifications are carried out in the **specified** cross-section class 1: **$U_{c/t}$ = 0.475 < 1** ok

2.2. lateral torsional buckling for bending around y-axis

c^2 = 568701 mm², buckling curve b ⇒ α_{LT} = 0.34, N_{cr} = 104.64 kN

2.2.1. load combination 1

moment coefficients for torsionally elastic bedding and shear field stiffness:
improved method: $\zeta_{0\vartheta} = 1.761$, $\zeta_{0S} = 0.230$ for $\beta_w = 1.132$, $\psi = 0.768$
critical moment due to torsionally elastic bedding:
$M_{cr,\vartheta} = \alpha_{cr} \cdot M_{Ed} = 95.42$ kNm with $\alpha_{cr} = 1.218$, $M_{Ed} = 78.34$ kNm
critical moment due to shear field stiffness:
$M_{cr,S} = \alpha_{cr} \cdot M_{Ed} = 339.11$ kNm with $\alpha_{cr} = 4.329$, $M_{Ed} = 78.34$ kNm
critical moment: $M_{cr} = M_{cr,\vartheta} + M_{cr,S} = 434.53$ kNm

2.2.2. 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	434.53	0.446	0.966	0.582	0.982	1.000	78.34	78.40	**0.999**

max U = 0.999 < 1 ok

3. final result

maximum utilisation U = 0.999 < 1 ok
c/t-utilisation U = 0.475 < 1 ok

verification succeeded

4. Selected Design Parameters of the National Annex

DIN EN 1993-1-1 (EC 3, Hochbau), NA Deutschland

chapter	value	definition
6.1(1)	permanent/transient situation	partial safety factors for structural steel
	γ_{M0} = 1.00	collapse of cross-section
	γ_{M1} = 1.10	instability
	γ_{M2} = 1.25	fracture cross-sections in tension
	accidental situation	partial safety factors for structural steel
	γ_{M0} = 1.00	collapse of cross-section
	γ_{M1} = 1.00	instability
	γ_{M2} = 1.25	fracture cross-sections in tension
6.3.2.2(2)	factor f to modify χ_{LT}	lateral torsional buckling general case
6.3.2.3(1)	$\lambda_{LT,0}$ = 0.40	slenderness eqn. (6.75)
	β = 0.75	correction factor eqn. (6.75)
6.3.2.3(2)	coefficient k_c from tab. 6.6	calculation of the reduction factor χ_{LT}

DIN EN 1993-1-2 (EC 3, Brandfall), NA Deutschland

chapter	value	definition
2.3(1)	event of fire	partial safety factor for
	$\gamma_{M,fi}$ = 1.00	mechanical failure