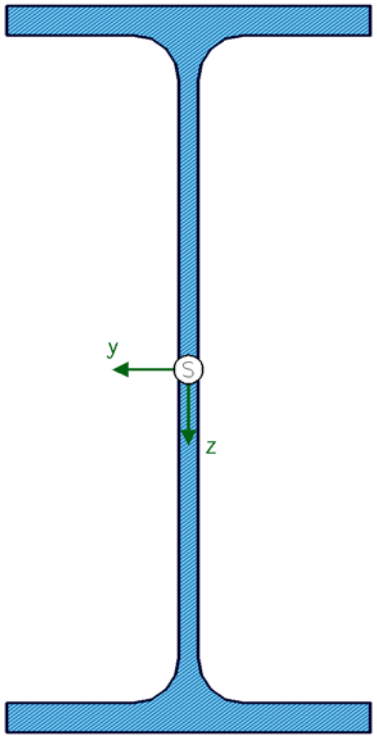
verification of stability EC 3-1-2 (12.10), NA: EC-standard parameters 4H-EC3ST version: 12/2021-1b

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} = 1.00

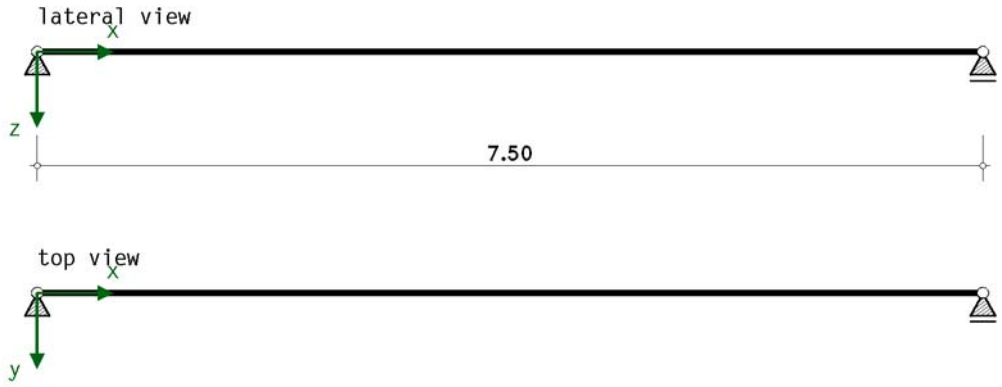
1.3. cross-section
material: S235 (St37) (E = 210000 N/mm^2, G = 80769 N/mm^2, $f_{y,k}$ = 235 N/mm^2)
section: IPE240
section scale 1:2.5



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

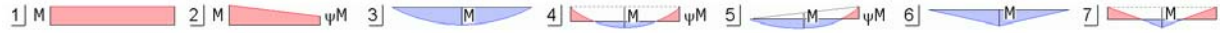
⊥ y-axis: β_y = 1.000, ⊥ z-axis: β_z = 1.000
warping restraint intensity β_0 = 1.000

1.8. design member forces (load combinations)

Lk	type	$M_{0y,d}$	ψ_y	$k_{c,y}$	ζ_y
	-y-	kNm	-	-	-
1	5	50.00	1.000	0.910	2.222

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 $S = G_S \cdot L_S$ = 240384.6 kN
shear field stiffness beam $S_i = S/n$ = 40064.1 kN with n = 6
torsionally elastic bedding
C_{100} = 5.2 kNm/m, $b_{T,max}$ = 40 mm acc. to EC 3-1-3, tab. 10.3 line 1
A = 0.00 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 EN 1993-1-1, $C_{D,C}$: end field and equidirectional rotation of beams
k_{ba} = 1.440, k_t = 1.372, k_{bR} = 0.894, k_A = 0.905, k_{bT} = 1.000
$C_{D,A}$ = 8.311 kNm/m, $C_{D,B}$ = 56.031 kNm/m, $C_{D,C}$ = 85.260 kNm/m, C_D = 6.671 kNm/m ⇒ **I_T^* = 59.97 cm⁴**
$I_T^* = I_T + \Delta I_T$ with I_T = 12.90 cm⁴, $\Delta I_T = (C_D \cdot c^2)/(G \cdot \pi^2)$ = 47.07 cm⁴, C_D = 6.671 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	t	c/t	ε	σ_1	σ_2	tab 5.2	α	ψ	k_σ	class
	mm	mm	-	-	N/mm²	N/mm²		-	-	-	-
1	41.9	9.8	4.28	1.000	147.94	147.94	single 1/1	---	---	---	1
2	41.9	9.8	4.28	1.000	147.94	147.94	single 1/1	---	---	---	1
3	190.4	6.2	30.71	1.000	122.37	-122.37	both 1/1	---	---	---	1
4	41.9	9.8	4.28	1.000	-147.94	-147.94	---------	---	---	---	---
5	41.9	9.8	4.28	1.000	-147.94	-147.94	---------	---	---	---	---

compressive stresses have a positive sign acc. to EC 3.
verifications are carried out in the **specified** cross-section class 2: **$U_{c/t}$ = 0.428 < 1** ok

2.2. lateral torsional buckling for bending around y-axis

c^2 = 476068 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: $\zeta_{0\vartheta}$ = 2.045, ζ_{0S} = 0.133 for β_w = 1.132, ψ = 1.000
critical moment due to torsionally elastic bedding:
$M_{cr,\vartheta} = \alpha_{cr} \cdot M_{Ed}$ = 128.15 kNm with α_{cr} = 2.563, M_{Ed} = 50.00 kNm
critical moment due to shear field stiffness:
$M_{cr,S} = \alpha_{cr} \cdot M_{Ed}$ = 1277.30 kNm with α_{cr} = 25.546, M_{Ed} = 50.00 kNm
critical moment: $M_{cr} = M_{cr,\vartheta} + M_{cr,S}$ = 1405.46 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	1405.46	0.248	1.000	0.497	1.000	1.000	50.00	86.25	**0.580**

max U = 0.580 < 1 ok

3. final result

maximum utilisation U = 0.580 < 1 ok
c/t-utilisation U = 0.428 < 1 ok

verification succeeded

4. Selected Design Parameters of the National Annex

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

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} = 1.00	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	lateral torsional buckling
	of χ_{LT} do not apply	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 EC-Standardparameter

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