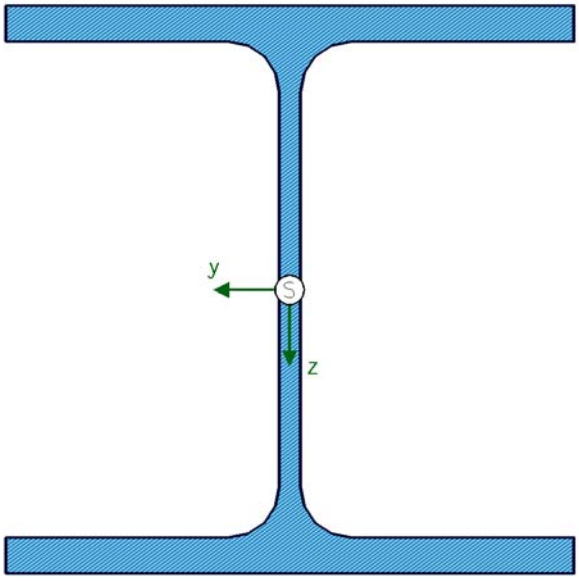
verification of stability EC 3-1-2 (12.10), NA: Deutschland 4H-EC3ST version: 12/2021-1b

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

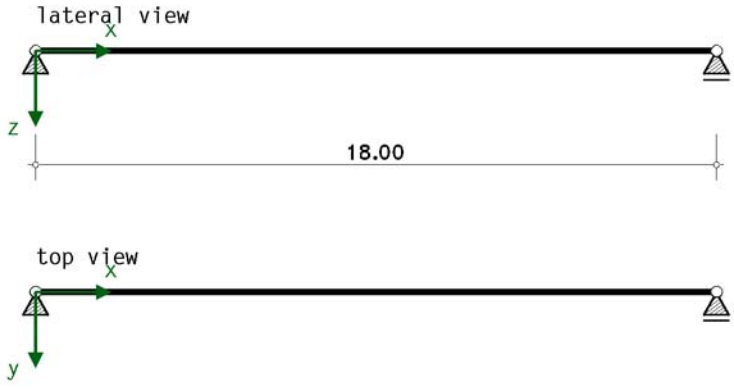
1.3. cross-section
material: S235 (St37) (E = 210000 N/mm^2, G = 80769 N/mm^2, $f_{y,k}$ = 235 N/mm^2)
section: HE300B
section scale 1:4.0



1.4. cross-section values (related to the centre of gravity S)
I_y = 25170.0 cm^4, I_z = 8560.0 cm^4, I_ζ = 25170.0 cm^4, I_η = 8560.0 cm^4, α = 0.0°
I_ω = 1688000.0 cm^6, I_T = 186.0 cm^4
W_y = 1680.0 cm^3, W_z = 571.0 cm^3, $W_{pl,y}$ = 1869.0 cm^3, $W_{pl,z}$ = 871.0 cm^3
$z_{m,y}$ = 0.0 mm, $z_{m,z}$ = -0.0 mm, A = 149.0 cm^2

1.5. load application point (related to the center of the surrounding rectangle)
y_{load} = 0.0 mm (centroid)
z_{load} = -150.0 mm (upper edge of cross-section)

1.6. static system
all bearings with fork restraint, bar length 18.000 [m]
no intermediate bearing in z-direction, no intermediate bearing in y-direction



1.7. buckling coefficients

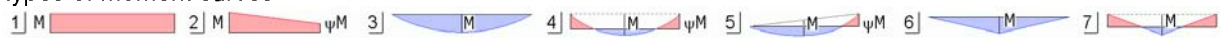
⊥ y-axis: β_y = 1.000, ⊥ z-axis: β_z = 1.000
warping restraint intensity β_0 = 1.000

1.8. design member forces (load combinations)

Lk	type -y-	$M_{0y,d}$ kNm	ψ_y -	$k_{c,y}$ -	ζ_y -
1	3	385.00	0.000	0.940	1.128

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 135.1, t_{nom} = 0.88 mm

shear field stiffness

ideal shear modulus $G_S = 10^4 / (K_1+K_2/L_S)$ = 1571.0 kN/m
with K_1 = 0.232 m/kN, K_2 = 36.800 m²/kN, L_S = 6.000 m
shear field stiffness $S = G_S \cdot L_S \cdot 0.2$ = 1885.2 kN
shear field stiffness beam $S_i = S/n$ = 942.6 kN with n = 2
required shear field stiffness of each beam req $S_i = (E \cdot I_\omega \cdot \pi^2/L^2 + G \cdot I_T + E \cdot I_{zl} \cdot \pi^2/L^2 \cdot h^2/4) \cdot 70/h^2$ = 134827.3 kN
with h = 300.0 mm, L = 18.000 m, I_ω = 1688000.00 cm⁶, I_T = 186.00 cm⁴, I_z = 8560.00 cm⁴
exist S_i = 942.6 kN < req S_i = 134827.3 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 = 0.00 kN/m (superimposed load between plate and beam), b_R = 310.0 mm, b_T = 43.0 mm
E = 210000 N/mm², c = 18.000 m (buckling length), I_{eff} = 3440000 mm⁴, s = 6.000 m (support width)
$C_{D,B}$: calculation acc. to DIN 18800, $C_{D,C}$: end field and opposite rotation of beams
k_{ba} = 2.500, k_t = 0.000, k_{bR} = 0.000, k_A = 0.000, k_{bT} = 0.000
$C_{D,A}$ = 7.750 kNm/m, $C_{D,B}$ = 233.323 kNm/m, $C_{D,C}$ = 240.800 kNm/m, C_D = 7.274 kNm/m ⇒ **I_T^* = 481.66 cm⁴**
$I_T^* = I_T + \Delta I_T$ with I_T = 186.00 cm⁴, $\Delta I_T = (C_D \cdot c^2)/(G \cdot \pi^2)$ = 295.66 cm⁴, C_D = 7.274 kNm/m, c = 18.000 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/mm²	σ_2 N/mm²	tab 5.2	α -	ψ -	k_σ -	class -
1	117.5	19.0	6.18	1.000	214.91	214.91	single 1/1	---	---	---	1
2	117.5	19.0	6.18	1.000	214.91	214.91	single 1/1	---	---	---	1
3	208.0	11.0	18.91	1.000	159.08	-159.08	both 1/1	---	---	---	1
4	117.5	19.0	6.18	1.000	-214.91	-214.91	---	---	---	---	---
5	117.5	19.0	6.18	1.000	-214.91	-214.91	---	---	---	---	---

compressive stresses have a positive sign acc. to EC 3.
verifications are carried out in the **specified** cross-section class 2: **$U_{c/t}$ = 0.618 < 1** ok

2.2. lateral torsional buckling for bending around y-axis

c^2 = 730174 mm², buckling curve b ⇒ α_{LT} = 0.34, N_{cr} = 547.58 kN

2.2.1. load combination 1

moment coefficients for torsionally elastic bedding and shear field stiffness:
$\zeta_{0\vartheta}$ = 1.128, ζ_{0S} = 1.128
critical moment due to torsionally elastic bedding:
$M_{cr,\vartheta} = \alpha_{cr} \cdot M_{Ed}$ = 483.53 kNm with α_{cr} = 1.256, M_{Ed} = 385.00 kNm
critical moment due to shear field stiffness:
$M_{cr,S} = \alpha_{cr} \cdot M_{Ed}$ = 318.99 kNm with α_{cr} = 0.829, M_{Ed} = 385.00 kNm
critical moment: $M_{cr} = M_{cr,\vartheta} + M_{cr,S}$ = 802.52 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	802.52	0.740	0.970	0.763	0.849	0.875	385.00	349.55	**1.101**

max U = 1.101 > 1 not ok !!

3. final result

maximum utilisation U = 1.101 > 1 not ok !!
c/t-utilisation U = 0.618 < 1 ok

resistance not ensured !!

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