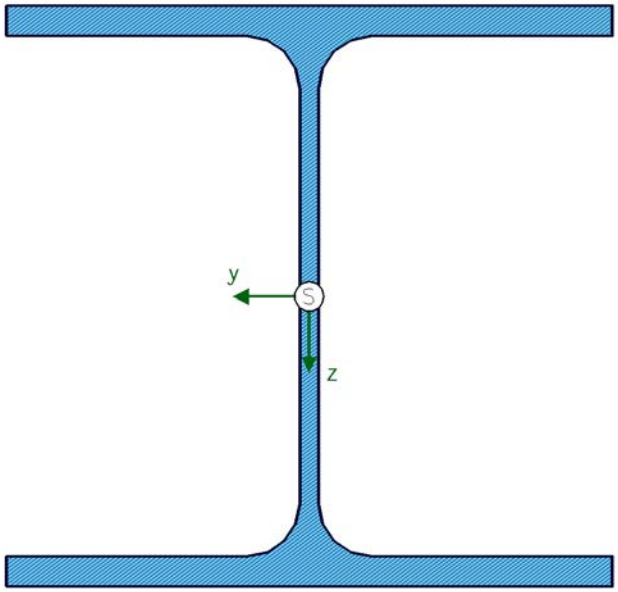
verification of stability EC 3-1-2 (12.10), NA: Deutschland 4H-EC3ST version: 12/2021-1b

1. input data

1.1. general information
verifications of stability acc. to EN 1993-1-1
lateral torsional buckling with the method of fictitious bars for N+My+Mz, interaction proof only with eqn. (6.61)

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

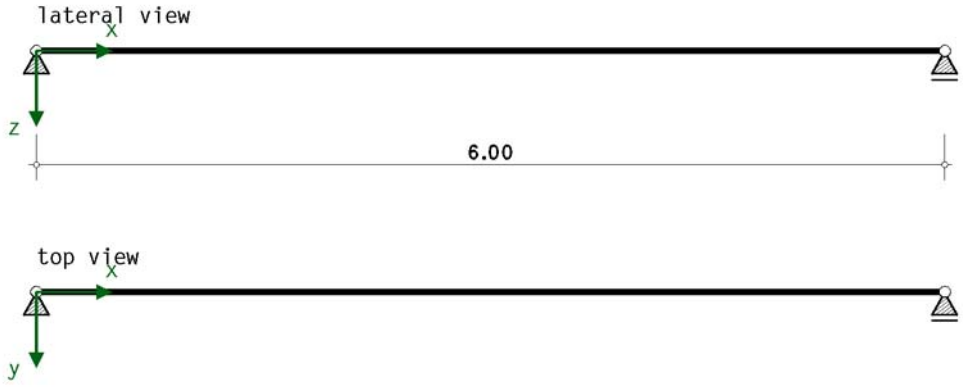
1.3. cross-section
material: S355 (St52) (E = 210000 N/mm^2, G = 80769 N/mm^2, $f_{y,k}$ = 355 N/mm^2)
section: HE240A
section scale 1:3.0



1.4. cross-section values (related to the centre of gravity S)
I_y = 7760.0 cm^4, I_z = 2770.0 cm^4, I_ζ = 7760.0 cm^4, I_η = 2770.0 cm^4, α = 0.0°
I_ω = 328500.0 cm^6, I_T = 41.7 cm^4
W_y = 675.0 cm^3, W_z = 231.0 cm^3, $W_{pl,y}$ = 745.0 cm^3, $W_{pl,z}$ = 352.0 cm^3
$z_{m,y}$ = -0.0 mm, $z_{m,z}$ = 0.0 mm, A = 76.8 cm^2, cross-section is torsionally soft

1.5. load application point (related to the center of the surrounding rectangle)
y_{load} = 0.0 mm (centroid)
z_{load} = -115.0 mm (upper edge of cross-section)

1.6. static system
all bearings with fork restraint, bar length 6.000 [m]
no intermediate bearing in z-direction, no intermediate bearing in y-direction



1.7. buckling coefficients

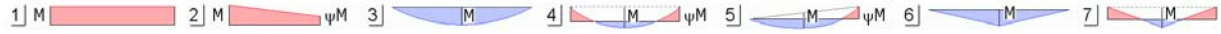
⊥ y-axis: β_y = 1.000, ⊥ z-axis: β_z = 1.000
warping restraint intensity β_0 = 1.000

1.8. design member forces (load combinations)

Lk	N_d kN	type -y-	$M_{0y,d}$ kNm	ψ_y -	$k_{c,y}$ -	ζ_y -	type -z-	$M_{0z,d}$ kNm	ψ_z -	$k_{c,z}$ -	ζ_z -
1	0.00	6	120.00	1.335	0.860	1.348	6	-12.00	0.000	0.860	1.348

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

types of moment curves



2. verifications

2.1. classification of cross-section

2.1.1. load combination 1 ⇒ section class 2

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	95.3	12.0	7.94	0.814	116.57	157.83	single 1/2	---	---	---	2
2	95.3	12.0	7.94	0.814	220.54	179.28	single 1/2	---	---	---	2
3	164.0	7.5	21.87	0.814	126.80	-126.80	both 1/1	---	---	---	1
4	95.3	12.0	7.94	0.814	-220.54	-168.56	---------	---	---	---	---
5	95.3	12.0	7.94	0.814	-116.57	-168.56	---------	---	---	---	---

compressive stresses have a positive sign acc. to EC 3.
verifications are carried out in the **specified** cross-section class 2
buckling of the individual sheets of the cross-section is to be verificated separately !!

2.2. lateral torsional buckling

2.2.1. flexural buckling for normal force

I_p = 10530 cm⁴, I_T = 42 cm⁴, i_p^2 = 13711 mm, c^2 = 32979 mm², i_m^2 = 13711 mm²
flexural buckling around y-axis:
i_y = 100.5 mm, β_z = 1.00 (⊥ z-axis), $L_{cr,z}$ = 6.000 m, λ_1 = 76.409
λ_y = 0.781, y-buckling curve b ⇒ α_y = 0.34, Φ_y = 0.904, χ_y = 0.736, **$N_{by,Rd}$ = 1824.18 kN**
flexural buckling around z-axis:
i_z = 60.1 mm, β_y = 1.00 (⊥ y-axis), $L_{cr,y}$ = 6.000 m, λ_1 = 76.409
λ_z = 1.308, z-buckling curve c ⇒ α_z = 0.49, Φ_z = 1.626, χ_z = 0.386, **$N_{bz,Rd}$ = 955.88 kN**

2.2.1.1. utilisations

Lk	N_d kN	U_y -	U_z -
1	0.00	**0.000**	**0.000**

2.2.2. lateral torsional buckling for bending around y-axis

c^2 = 32979 mm², buckling curve b ⇒ α_{LT} = 0.34, N_{cr} = 1594.76 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	285.83	0.962	0.934	0.943	0.723	0.774	120.00	186.15	**0.645**

2.2.3. lateral torsional buckling for bending around z-axis

c^2 = 32979 mm², buckling curve b ⇒ α_{LT} = 0.34, N_{cr} = 4467.64 kN

2.2.3.1. 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	1093.45	0.338	0.960	0.532	1.000	1.000	-12.00	113.60	**0.106**

2.2.4. interaction

Lk	eqn.	C_{my} -	k_{yy} -	C_{mLT} -	k_{zy} -	C_{mz} -	k_{zz} -	k_{yz} -	U -
1	(6.61)	0.900	0.900	0.900	---	---	---	0.540	0.637
	(6.62)	---	---	0.900	1.000	0.900	0.900	---	**0.740**

max U = 0.740 < 1 ok

3. final result

maximum utilisation U = 0.740 < 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