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

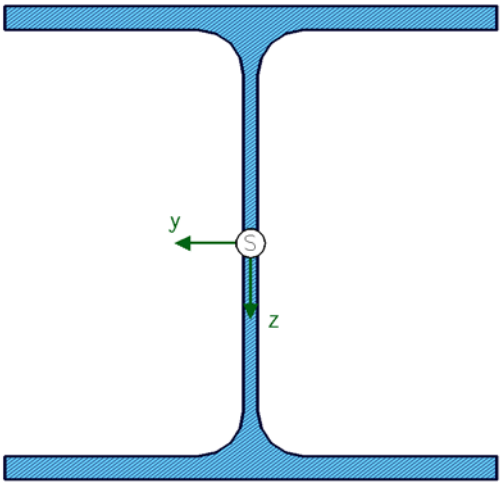
Vorbemerkungen
Das Bimoment wird by einen zusätzlichen Ansatz for das internal moment around z-axis reqasst:
Lk 1: ΔMoz,d = 5.05 kNm
Lk 2: ΔMoz,d = 7.75 kNm

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+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

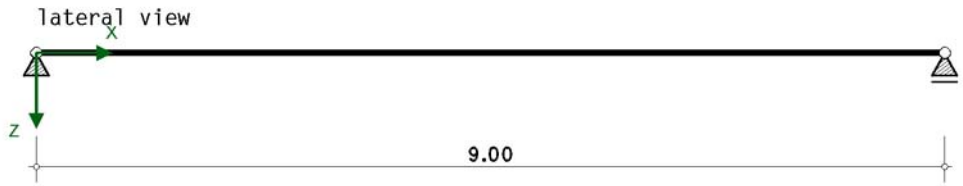
1.3. cross-section
material: S235 (St37) (E = 210000 N/mm², G = 80769 N/mm², $f_{y,k}$ = 235 N/mm²)
section: HE260A
section scale 1:4.0

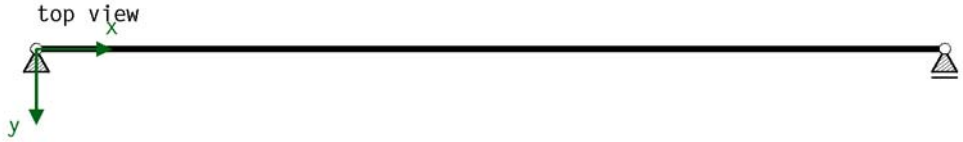


1.4. cross-section values (related to the centre of gravity S)
I_y = 10450.0 cm⁴, I_z = 3670.0 cm⁴, I_ζ = 10450.0 cm⁴, I_η = 3670.0 cm⁴, α = 0.0°
I_ω = 516400.0 cm⁶, I_T = 52.6 cm⁴
W_y = 836.0 cm³, W_z = 282.0 cm³, $W_{pl,y}$ = 920.0 cm³, $W_{pl,z}$ = 430.0 cm³
$z_{m,y}$ = 0.0 mm, $z_{m,z}$ = -0.0 mm, A = 86.8 cm², 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} = -125.0 mm (upper edge of cross-section)

1.6. static system
all bearings with fork restraint, bar length 9.000 [m]
no intermediate bearing in z-direction, no intermediate bearing in y-direction





1.7. buckling coefficients

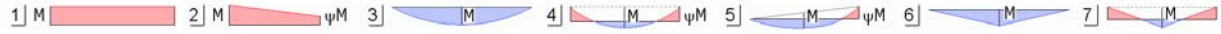
⊥ y-axis: β_y = 1.000, ⊥ z-axis: β_z = 1.000
warping restraint intensity β_0 = 1.000

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	68.30	3	60.90	0.000	0.940	1.128	3	27.45	0.000	0.940	1.128
2	68.30	3	41.90	1.000	0.940	1.128	3	41.65	1.000	0.940	1.128

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 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	102.3	12.5	8.18	1.000	174.31	97.83	single 1/1	---	---	---	**1**
2	102.3	12.5	8.18	1.000	-20.16	56.32	single 3/1	0.264	---	---	1
3	177.0	7.5	23.60	1.000	59.44	-43.71	both 3/1	0.609	---	---	1
4	102.3	12.5	8.18	1.000	35.90	-40.58	single 2/1	0.469	---	---	1
5	102.3	12.5	8.18	1.000	-158.57	-61.34	---------	---	---	---	---

2.1.2. load combination 2 ⇒ 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	102.3	12.5	8.18	1.000	203.02	86.98	single 1/1	---	---	---	**1**
2	102.3	12.5	8.18	1.000	-92.05	23.99	single 3/1	0.207	---	---	1
3	177.0	7.5	23.60	1.000	43.35	-27.62	both 3/1	0.609	---	---	1
4	102.3	12.5	8.18	1.000	107.79	-8.25	single 2/1	0.929	---	---	1
5	102.3	12.5	8.18	1.000	-187.28	-39.74	---------	---	---	---	---

compressive stresses have a positive sign acc. to EC 3.
verifications are carried out in the **specified** cross-section class 2: **$U_{c/t}$ = 0.818 < 1** ok

2.2. lateral torsional buckling

2.2.1. flexural buckling for normal force

I_p = 14120 cm⁴, I_T = 53 cm⁴, i_p^2 = 16267 mm, c^2 = 59312 mm², i_m^2 = 16267 mm²
flexural buckling around y-axis:
i_y = 109.7 mm, β_z = 1.00 (⊥ z-axis), $L_{cr,z}$ = 9.000 m, λ_1 = 93.913
λ_y = 0.873, y-buckling curve b ⇒ α_y = 0.34, Φ_y = 0.996, χ_y = 0.678, **$N_{by,Rd}$ = 1257.69 kN**
flexural buckling around z-axis:
i_z = 65.0 mm, β_y = 1.00 (⊥ y-axis), $L_{cr,y}$ = 9.000 m, λ_1 = 93.913
λ_z = 1.474, z-buckling curve c ⇒ α_z = 0.49, Φ_z = 1.898, χ_z = 0.323, **$N_{bz,Rd}$ = 599.28 kN**

2.2.1.1. utilisations

Lk	N_d kN	U_y -	U_z -
1	68.30	**0.054**	**0.114**
2	68.30	0.054	0.114

2.2.2. lateral torsional buckling for bending around y-axis

c^2 = 59312 mm², buckling curve b ⇒ α_{LT} = 0.34, N_{cr} = 939.07 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	200.14	1.039	0.973	1.014	0.676	0.694	60.90	136.40	**0.446**
2	200.14	1.039	0.973	1.014	0.676	0.694	41.90	136.40	0.307

2.2.3. lateral torsional buckling for bending around z-axis

c^2 = 59312 mm², buckling curve b ⇒ α_{LT} = 0.34, N_{cr} = 2673.93 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	734.60	0.371	0.981	0.547	1.000	1.000	27.45	91.86	0.299
2	734.60	0.371	0.981	0.547	1.000	1.000	41.65	91.86	**0.453**

2.2.4. interaction

Lk	eqn.	C_{my} -	k_{yy} -	C_{mLT} -	k_{zy} -	C_{mz} -	k_{zz} -	k_{yz} -	U -
1	(6.61)	0.950	0.985	0.950	---	---	---	0.661	0.691
	(6.62)	---	---	0.950	0.984	0.950	1.102	---	0.882
2	(6.61)	0.950	0.985	0.950	---	---	---	0.661	0.656
	(6.62)	---	---	0.950	0.984	0.950	1.102	---	**0.916**

max U = 0.916 < 1 ok

3. final result

maximum utilisation U = 0.916 < 1 ok
c/t-utilisation U = 0.818 < 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	lateral torsional buckling
	χ_{LT}	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