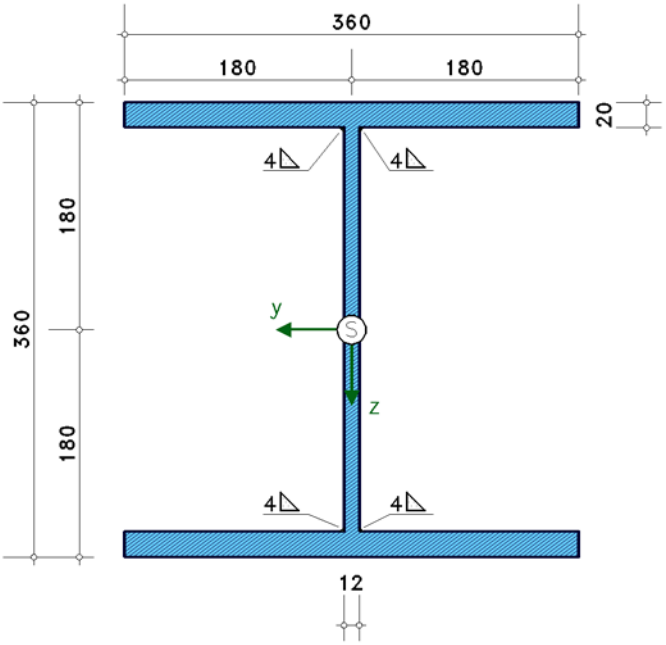
verification of stability EC 3-1-2 (12.10), NA: Deutschland 4H-EC3ST version: 12/2021-1b

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 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

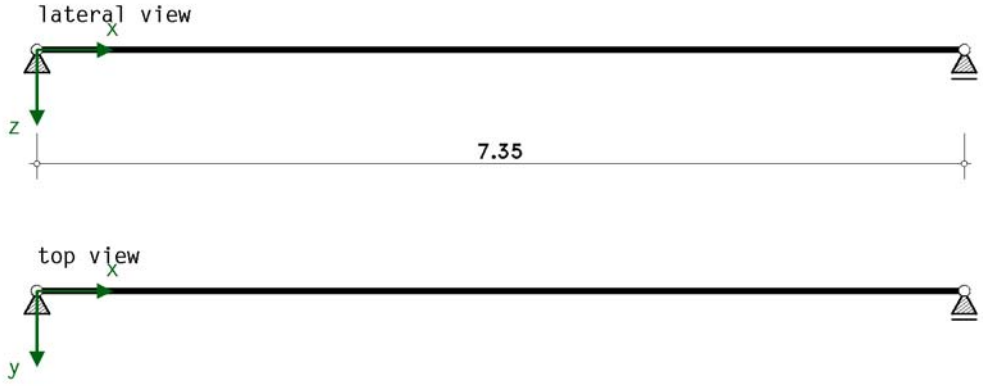
1.3. cross-section
material: S275 (St44) (E = 210000 N/mm², G = 80769 N/mm², $f_{y,k}$ = 275 N/mm²)
designation: column welded
section scale 1:6.0



1.4. cross-section values (related to the centre of gravity S)
I_y = 44940.8 cm⁴, I_z = 15556.6 cm⁴, I_ζ = 44940.8 cm⁴, I_η = 15556.6 cm⁴, α = 0.0°
I_ω = 4494528.0 cm⁶, I_T = 207.6 cm⁴
W_y = 2496.7 cm³, W_z = 864.3 cm³, $W_{pl,y}$ = 2794.8 cm³, $W_{pl,z}$ = 1296.0 cm³
$z_{m,y}$ = 0.0 mm, $z_{m,z}$ = 0.0 mm, A = 182.4 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} = 0.0 mm (centroid)

1.6. static system
all bearings with fork restraint, bar length 7.350 [m]
no intermediate bearing in z-direction, no intermediate bearing in y-direction



1.7. buckling coefficients

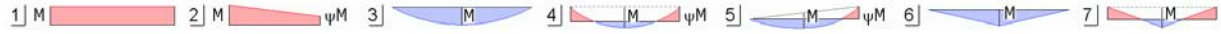
⊥ y-axis: β_y = 2.000, ⊥ z-axis: β_z = 2.000
warping restraint intensity β_0 = 1.000

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	434.50	2	215.80	0.351	0.824	1.243	2	0.00	0.000	0.752	1.770
2	309.30	2	258.20	0.206	0.792	1.543	2	0.00	0.000	0.752	1.770
3	453.50	2	102.30	0.773	0.930	0.732	2	45.60	0.000	0.752	1.770
4	341.00	2	73.60	0.799	0.938	0.732	2	76.10	0.000	0.752	1.770
5	434.50	2	-60.10	-0.790	0.628	1.128	2	45.60	0.000	0.752	1.770
6	309.30	2	-168.80	-0.310	0.697	2.599	2	76.10	0.000	0.752	1.770

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	168.3	20.0	8.42	0.924	105.45	105.45	single 1/2	---	---	---	2
2	168.3	20.0	8.42	0.924	105.45	105.45	single 1/2	---	---	---	2
3	308.7	12.0	25.72	0.924	103.56	-55.92	both 3/1	0.713	---	---	1
4	168.3	20.0	8.42	0.924	-57.81	-57.81	---	---	---	---	---
5	168.3	20.0	8.42	0.924	-57.81	-57.81	---	---	---	---	---

2.1.2. load combination 2 ⇒ 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	168.3	20.0	8.42	0.924	114.63	114.63	single 1/2	---	---	---	2
2	168.3	20.0	8.42	0.924	114.63	114.63	single 1/2	---	---	---	2
3	308.7	12.0	25.72	0.924	112.37	-78.45	both 3/1	0.652	---	---	1
4	168.3	20.0	8.42	0.924	-80.71	-80.71	---	---	---	---	---
5	168.3	20.0	8.42	0.924	-80.71	-80.71	---	---	---	---	---

2.1.3. load combination 3 ⇒ 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	168.3	20.0	8.42	0.924	116.32	65.28	single 1/2	---	---	---	2
2	168.3	20.0	8.42	0.924	10.80	61.85	single 1/2	---	---	---	2
3	308.7	12.0	25.72	0.924	62.66	-12.94	both 3/1	0.723	---	---	1
4	168.3	20.0	8.42	0.924	38.93	-12.12	single 2/1	0.763	---	---	1
5	168.3	20.0	8.42	0.924	-66.60	-13.83	---	---	---	---	---

2.1.4. load combination 4 ⇒ 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	168.3	20.0	8.42	0.924	134.59	49.40	single 1/2	---	---	---	2
2	168.3	20.0	8.42	0.924	-41.52	43.67	single 3/1	0.487	---	---	1
3	308.7	12.0	25.72	0.924	45.89	-8.50	both 3/1	0.667	---	---	1
4	168.3	20.0	8.42	0.924	78.91	-6.28	single 2/1	0.926	---	---	1
5	168.3	20.0	8.42	0.924	-97.20	-9.15	---	---	---	---	---

2.1.5. load combination 5 ⇒ 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	168.3	20.0	8.42	0.924	53.85	2.80	single 1/2	---	---	---	2
2	168.3	20.0	8.42	0.924	-51.68	-0.63	single 0/0	---	---	---	---
3	308.7	12.0	25.72	0.924	1.61	46.03	both 3/1	0.713	---	---	1
4	168.3	20.0	8.42	0.924	99.32	48.27	single 1/2	---	---	---	2
5	168.3	20.0	8.42	0.924	-6.21	44.84	single 3/1	0.122	---	---	1

2.1.6. load combination 6 ⇒ 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	168.3	20.0	8.42	0.924	41.16	-44.03	single 2/1	0.483	---	---	1
2	168.3	20.0	8.42	0.924	-134.95	-46.90	---------	---	---	---	---
3	308.7	12.0	25.72	0.924	-45.42	79.33	both 3/1	0.652	---	---	1
4	168.3	20.0	8.42	0.924	168.86	83.67	single 1/2	---	---	---	2
5	168.3	20.0	8.42	0.924	-7.24	77.95	single 3/1	0.085	---	---	1

compressive stresses have a positive sign acc. to EC 3.
the verifications are carried out in the smallest possible cross-section class 2: $U_{c/t} = 0.911 < 1$ ok

2.2. lateral torsional buckling

2.2.1. flexural buckling for normal force

$I_p = 60497$ cm⁴, $I_T = 208$ cm⁴, $i_p^2 = 33167$ mm, $c^2 = 227965$ mm², $i_m^2 = 33167$ mm²
flexural buckling around y-axis:
$i_y = 157.0$ mm, $\beta_z = 2.00$ (⊥ z-axis), $L_{cr,z} = 14.700$ m, $\lambda_1 = 86.815$
$\lambda_y = 1.079$, y-buckling curve b ⇒ $\alpha_y = 0.34$, $\Phi_y = 1.231$, $\chi_y = 0.548$, **$N_{by,Rd} = 2499.02$ kN**
flexural buckling around z-axis:
$i_z = 92.4$ mm, $\beta_y = 2.00$ (⊥ y-axis), $L_{cr,y} = 14.700$ m, $\lambda_1 = 86.815$
$\lambda_z = 1.833$, z-buckling curve c ⇒ $\alpha_z = 0.49$, $\Phi_z = 2.581$, $\chi_z = 0.227$, **$N_{bz,Rd} = 1036.91$ kN**

2.2.1.1. utilisations

Lk	N_d kN	U_y -	U_z -
1	434.50	0.174	0.419
2	309.30	0.124	0.298
3	453.50	**0.181**	**0.437**
4	341.00	0.136	0.329
5	434.50	0.174	0.419
6	309.30	0.124	0.298

2.2.2. lateral torsional buckling for bending around y-axis

$c^2 = 227965$ mm², buckling curve c ⇒ $\alpha_{LT} = 0.49$, $N_{cr} = 1492.10$ kN

2.2.2.1. utilisations

Lk	class	M_{cr} kNm	λ_{LT} -	f -	Φ_{LT} -	χ_{LT} m	$\chi_{LT,mod}$ m	M_{Ed} kNm	$M_{b,Rd}$ kNm	U -
1	2 ⇒ $W_{pl,y}$	885.53	0.932	0.915	0.956	0.681	0.744	215.80	520.13	0.415
2	2 ⇒ $W_{pl,y}$	1099.26	0.836	0.896	0.869	0.741	0.827	258.20	577.65	**0.447**
3	2 ⇒ $W_{pl,y}$	521.49	1.214	0.977	1.252	0.518	0.530	102.30	370.14	0.276
4	2 ⇒ $W_{pl,y}$	521.49	1.214	0.980	1.252	0.518	0.528	73.60	369.14	0.199
5	2 ⇒ $W_{pl,y}$	803.60	0.978	0.826	1.000	0.653	0.790	-60.10	552.14	0.109
6	2 ⇒ $W_{pl,y}$	1851.57	0.644	0.856	0.716	0.860	1.000	-168.80	698.70	0.242

2.2.3. lateral torsional buckling for bending around z-axis

$c^2 = 227965$ mm², buckling curve c ⇒ $\alpha_{LT} = 0.49$, $N_{cr} = 4310.48$ kN

2.2.3.1. utilisations

Lk	class	M_{cr} kNm	λ_{LT} -	f -	Φ_{LT} -	χ_{LT} m	$\chi_{LT,mod}$ m	M_{Ed} kNm	$M_{b,Rd}$ kNm	U -
1	2 ⇒ $W_{pl,z}$	3643.53	0.313	0.935	0.515	1.000	1.000	0.00	324.00	0.000
2	2 ⇒ $W_{pl,z}$	3643.53	0.313	0.935	0.515	1.000	1.000	0.00	324.00	0.000
3	2 ⇒ $W_{pl,z}$	3643.53	0.313	0.935	0.515	1.000	1.000	45.60	324.00	0.141
4	2 ⇒ $W_{pl,z}$	3643.53	0.313	0.935	0.515	1.000	1.000	76.10	324.00	**0.235**
5	2 ⇒ $W_{pl,z}$	3643.53	0.313	0.935	0.515	1.000	1.000	45.60	324.00	0.141
6	2 ⇒ $W_{pl,z}$	3643.53	0.313	0.935	0.515	1.000	1.000	76.10	324.00	0.235

2.2.4. interaction

Lk	eqn.	C_{my} -	k_{yy} -	C_{mLT} -	k_{zy} -	C_{mz} -	k_{zz} -	k_{yz} -	U -
1	(6.61)	0.740	0.843	0.740	---	---	---	0.571	0.524
	(6.62)	---	---	0.740	0.915	0.600	0.952	---	0.798
2	(6.61)	0.682	0.750	0.682	---	---	---	0.510	0.459
	(6.62)	---	---	0.682	0.931	0.600	0.851	---	0.714
3	(6.61)	0.909	1.041	0.909	---	---	---	0.580	0.551
	(6.62)	---	---	0.909	0.934	0.600	0.967	---	**0.832**
4	(6.61)	0.920	1.020	0.920	---	---	---	0.526	0.463
	(6.62)	---	---	0.920	0.951	0.600	0.876	---	0.724
5	(6.61)	0.400	0.456	0.400	---	---	---	0.571	0.304
	(6.62)	---	---	0.400	0.721	0.600	0.952	---	0.631
6	(6.61)	0.476	0.523	0.476	---	---	---	0.510	0.370

Lk	eqn.	C_{my} -	k_{yy} -	C_{mLT} -	k_{zy} -	C_{mz} -	k_{zz} -	k_{yz} -	U -
	(6.62)	---	---	0.476	0.868	0.600	0.851	---	0.708

max U = 0.832 < 1 ok

3. final result

maximum utilisation U = 0.832 < 1 ok
c/t-utilisation U = 0.911 < 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