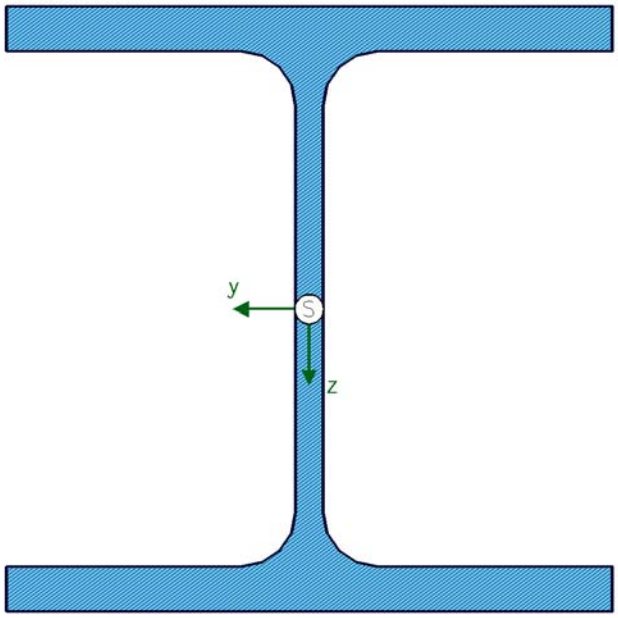
verification of stability EC 3-1-2 (12.10), NA: Deutschland 4H-EC3ST version: 12/2021-1b

1. input data

1.1. general information
verifications of stability in case of fire acc. to EN 1993-1-2
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. (4.21a,c)

1.2. safety factor of material
resistance of cross-sections γ_{M0} = 1.00
resistance of members in stability failure γ_{M1} = 1.10
resistance of components in the event of fire $\gamma_{M,fi}$ = 1.00

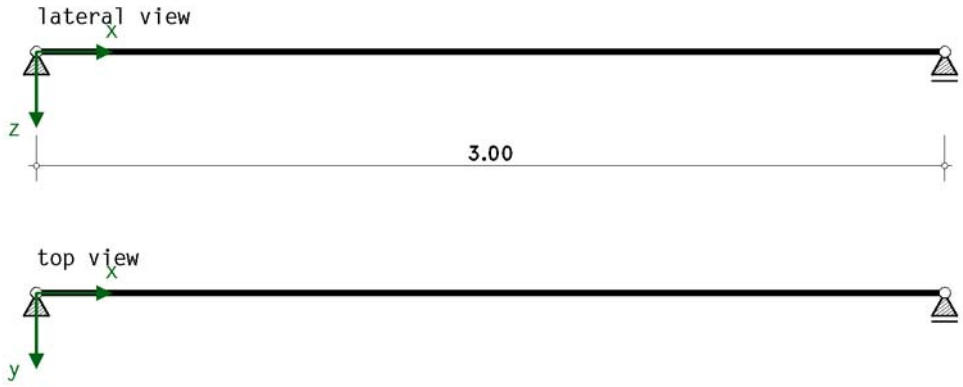
1.3. cross-section
material: S235 (St37) (E = 210000 N/mm^2, G = 80769 N/mm^2, $f_{y,k}$ = 235 N/mm^2)
section: HE200B
section scale 1:2.5



1.4. cross-section values (related to the centre of gravity S)
I_y = 5700.0 cm^4, I_z = 2000.0 cm^4, I_ζ = 5700.0 cm^4, I_η = 2000.0 cm^4, α = 0.0°
I_ω = 171100.0 cm^6, I_T = 59.5 cm^4
W_y = 570.0 cm^3, W_z = 200.0 cm^3, $W_{pl,y}$ = 643.0 cm^3, $W_{pl,z}$ = 306.0 cm^3
$z_{m,y}$ = 0.0 mm, $z_{m,z}$ = 0.0 mm, A = 78.1 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} = 0.0 mm (centroid)

1.6. static system
all bearings with fork restraint, bar length 3.000 [m]
no intermediate bearing in z-direction, no intermediate bearing in y-direction



1.7. buckling coefficients

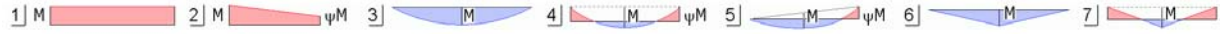
⊥ y-axis: β_y = 0.500, ⊥ z-axis: β_z = 0.500
warping restraint intensity β_0 = 1.000

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	800.00	2	50.00	-1.000	0.602	2.555	2	50.00	-1.000	0.602	2.555

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

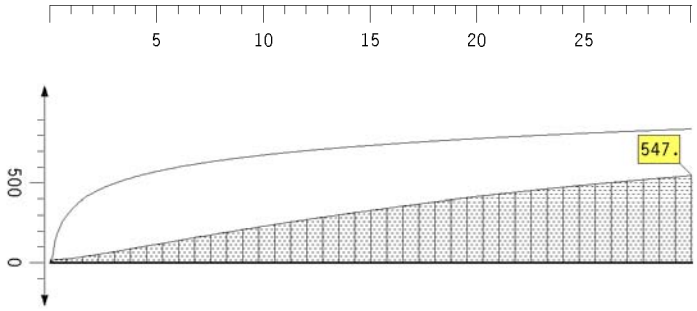


1.9. fire design

thermal action due to the standard curve, fire resistance time t = 30.0 min
section all sides flamed
thermal insulation protection by plaster cladding s. EC 3-1-2, appendix AA:
thermal conductivity λ_p = 0.12 W/(m·K), specific heat capacity c_p = 1100 J/(kg·K), maximum density ρ_p = 550 kg/m³
thickness of insulating material d_p = 5.0 mm
maximum density steel 7850.0 kg/m³, room temperature 20.0 °C
fire design at load level
adjustment factors of bending moments for uneven temperature distribution
across the cross section κ_1 = 1.00, along the beam κ_2 = 1.00

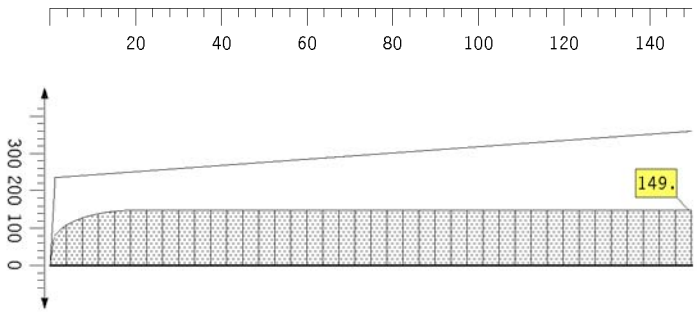
2. cross-section temperature

internal development of the fire-stressed profile-following cladding A_p = 1151.1 mm²/mm
section factor of the protected component A_p/V = 1151.1 / 7808.1 ·10³ = 147.4 1/m
temperature development:



temperature in °C
fire time in min
max T_a = 547.2°C
max t = 30 min

cross-section temperature acc. to t = 30.0 min: **T_a = 547.2 °C**
reduction factors: $k_{y,fi}$ = 0.634, $k_{E,fi}$ = 0.463
material parameters: $f_{y,fi}$ = 148.9 N/mm², E_{fi} = 97242.3 N/mm²
limit of strains: $\varepsilon_{y,fi}$ = 20‰, $\varepsilon_{t,fi}$ = 150‰
stress-strain line:



stress in N/mm²
elongation in ‰
max $f_{y,fi}$ = 148.9 N/mm²
max ε_{fi} = 150.0‰

fire design at load level with the simple design method acc. to EC 3-1-2, 4.2

3. verifications

3.1. classification of cross-section

3.1.1. 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	77.5	15.0	5.17	0.850	433.57	239.82	single 1/1	---	---	---	1
2	77.5	15.0	5.17	0.850	-66.43	127.32	single 3/1	0.343	---	---	1
3	134.0	9.0	14.89	0.850	161.20	43.66	both 3/1	1.000	---	---	1
4	77.5	15.0	5.17	0.850	271.29	77.54	single 1/1	---	---	---	1
5	77.5	15.0	5.17	0.850	-228.71	-34.96	single 0/0	---	---	---	---

compressive stresses have a positive sign acc. to EC 3.
classification of cross-section in case of fire acc. to EC 3-1-2, 4.2.2.
the verifications are carried out in the smallest possible cross-section class 1: $U_{c/t} = 0.675 < 1$ ok

3.2. lateral torsional buckling

3.2.1. flexural buckling for normal force

$I_p = 7700$ cm⁴, $I_T = 60$ cm⁴, $i_p^2 = 9859$ mm, $c^2 = 4747$ mm², $i_m^2 = 9859$ mm²
flexural buckling around y-axis:
$i_y = 85.4$ mm, $\beta_z = 0.50$ (⊥ z-axis), $L_{cr,z} = 1.500$ m, $\lambda_1 = 80.284$
$\lambda_y = 0.219$, y-buckling curve 'fire' ⇒ $\alpha_y = 0.65$, $\Phi_y = 0.595$, $\chi_y = 0.871$, **$N_{by,Rd} = 1012.69$ kN**
flexural buckling around z-axis:
$i_z = 50.6$ mm, $\beta_y = 0.50$ (⊥ y-axis), $L_{cr,y} = 1.500$ m, $\lambda_1 = 80.284$
$\lambda_z = 0.369$, z-buckling curve 'fire' ⇒ $\alpha_z = 0.65$, $\Phi_z = 0.688$, $\chi_z = 0.788$, **$N_{bz,Rd} = 916.49$ kN**

3.2.1.1. utilisations

Lk	N_d kN	U_y -	U_z -
1	800.00	**0.790**	**0.873**

3.2.2. lateral torsional buckling for bending around y-axis

$c^2 = 4747$ mm², buckling curve 'fire' ⇒ $\alpha_{LT} = 0.65$, $N_{cr} = 8531.05$ kN

3.2.2.1. utilisations

event of fire: $M_{Ed} = \kappa_1 \cdot \kappa_2 \cdot M_{Ed}$

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	1 ⇒ $W_{pl,y}$	1501.52	0.253	1.000	0.614	0.852	0.852	50.00	81.58	**0.613**

3.2.3. lateral torsional buckling for bending around z-axis

$c^2 = 4747$ mm², buckling curve 'fire' ⇒ $\alpha_{LT} = 0.65$, $N_{cr} = 24313.49$ kN

3.2.3.1. utilisations

event of fire: $M_{Ed} = \kappa_1 \cdot \kappa_2 \cdot M_{Ed}$

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	1 ⇒ $W_{pl,z}$	4279.33	0.103	1.000	0.539	0.937	0.937	50.00	42.67	**1.172**

3.2.4. interaction

Lk	eqn.	μ_y -	k_y -	μ_{LT} -	k_{LT} -	μ_z -	k_z -	U -
1	(4.21a)	0.800	0.368	---	---	0.800	0.302	1.313
	(4.21b)	---	---	-0.012	1.000	0.800	0.302	**1.817**

max U = 1.817 > 1 not ok !!

4. final result

maximum utilisation	U = 1.817 > 1 not ok !!
c/t-utilisation	U = 0.675 < 1 ok

resistance not ensured !!

5. 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

chapter	value	definition
	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

6. Regulations

DIN EN 1990, Eurocode 0: Grundlagen der Tragwerksplanung;
Deutsche Fassung EN 1990:2002 + A1:2005 + A1:2005/AC:2010, Ausgabe Dezember 2010
DIN EN 1990/NA, Nationaler Anhang zur DIN EN 1990, Ausgabe Dezember 2010

DIN EN 1991-1-2, Eurocode 1: Einwirkungen auf Tragwerke - Teil 1-2: Allgemeine Einwirkungen - Brandeinwirkungen auf Tragwerke; Deutsche Fassung EN 1991-1-2, Ausgabe Dezember 2010
DIN EN 1991-1-2/NA, Nationaler Anhang zur DIN EN 1991-1-2, Ausgabe September 2015

DIN EN 1993-1-1, Eurocode 3: Bemessung und Konstruktion von Stahlbauten - Teil 1-1: Allgemeine Bemessungsregeln und Regeln für den Hochbau;
Deutsche Fassung EN 1993-1-1:2005 + AC:2009, Ausgabe Dezember 2010
DIN EN 1993-1-1/A1, Ergänzungen zur DIN EN 1993-1-1, Ausgabe Juli 2014
DIN EN 1993-1-1/NA, Nationaler Anhang zur DIN EN 1993-1-1, Ausgabe Dezember 2018

DIN EN 1993-1-2, Eurocode 3: Bemessung und Konstruktion von Stahlbauten - Teil 1-2: Allgemeine Regeln - Tragwerksbemessung für den Brandfall; Deutsche Fassung EN 1993-1-2, Ausgabe Dezember 2010
DIN EN 1993-1-2/NA, Nationaler Anhang zur DIN EN 1993-1-2, Ausgabe Dezember 2010