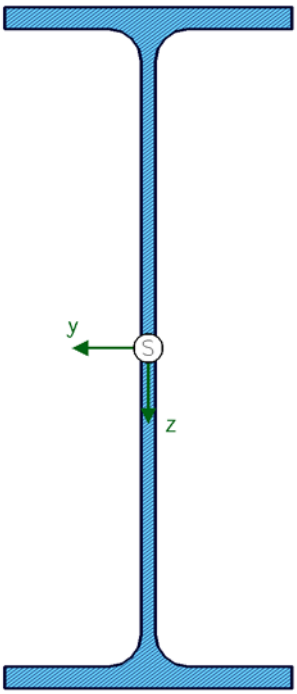
verification of stability EC 3-1-2 (12.10), NA: Deutschland 4H-EC3ST version: 12/2021-1b

1. input data

1.1. general information
verifications of stability in case of fire acc. to EN 1993-1-2
lateral torsional buckling with the method of fictitious bars for N+My, 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

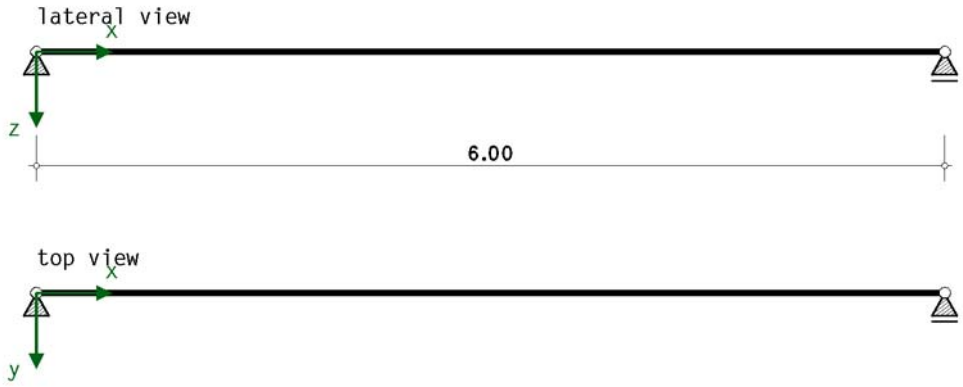
1.3. cross-section
material: S235 (St37) (E = 210000 N/mm^2, G = 80769 N/mm^2, $f_{y,k}$ = 235 N/mm^2)
section: IPE450
section scale 1:5.0



1.4. cross-section values (related to the centre of gravity S)
I_y = 33740.0 cm^4, I_z = 1680.0 cm^4, I_ζ = 33740.0 cm^4, I_η = 1680.0 cm^4, α = 0.0°
I_ω = 791000.0 cm^6, I_T = 67.1 cm^4
W_y = 1500.0 cm^3, W_z = 176.0 cm^3, $W_{pl,y}$ = 1702.0 cm^3, $W_{pl,z}$ = 275.0 cm^3
$z_{m,y}$ = 0.0 mm, $z_{m,z}$ = 0.0 mm, A = 98.8 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} = 0.0 mm (shear center)

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

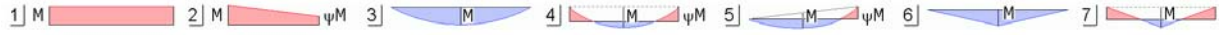
⊥ y-axis: β_y = 1.000, ⊥ z-axis: β_z = 1.000
warping restraint intensity β_0 = 1.000

1.8. design member forces (load combinations)

Lk	N_d kN	type -y-	$M_{0y,d}$ kNm	ψ_y -	$k_{c,y}$ -	ζ_y -
1	136.50	3	71.50	0.000	0.940	1.128

N_d: constant axial force in the bar; 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. fire design

thermal action due to the standard curve, fire resistance time t = 12.2 min
emissivity of the cross-section surface of untreated steel steel
section all sides flamed
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

surface of the section exposed to fire A_m = 1605.1 mm²/mm
section factor of the unprotected component A_m/V = 1605.1 / 9882.1 ·10³ = 162.4 1/m
fire-stressed inner surface of the enclosing box A_b = 1280.0 mm²/mm
section factor for the enclosing box A_b/V = 1280.0 / 9882.1 ·10³ = 129.5 1/m
correction factor k_{sh} = (A_b/V) / (A_m/V) = 129.5 / 162.4 = 0.797, I-section: 0.9·k_{sh} = 0.718
cross-section temperature acc. to t = 12.2 min: **T_a = 516.4 °C**
reduction factors: $k_{y,fi}$ = 0.729, $k_{E,fi}$ = 0.552
material parameters: $f_{y,fi}$ = 171.4 N/mm², E_{fi} = 116022.5 N/mm²

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	69.3	14.6	4.75	0.850	59.95	59.95	single 1/1	---	---	---	1
2	69.3	14.6	4.75	0.850	59.95	59.95	single 1/1	---	---	---	1
3	378.8	9.4	40.30	0.850	53.95	-26.32	both 3/1	0.582	---	---	1
4	69.3	14.6	4.75	1.171	-32.32	-32.32	---	---	---	---	---
5	69.3	14.6	4.75	1.171	-32.32	-32.32	---	---	---	---	---

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

3.2. lateral torsional buckling

3.2.1. flexural buckling for normal force

I_p = 35420 cm⁴, I_T = 67 cm⁴, i_p^2 = 35850 mm, c^2 = 103116 mm², i_m^2 = 35850 mm²
flexural buckling around y-axis:
i_y = 184.8 mm, β_z = 1.00 (⊥ z-axis), $L_{cr,z}$ = 6.000 m, λ_1 = 81.745
λ_y = 0.397, y-buckling curve 'fire' ⇒ α_y = 0.65, Φ_y = 0.708, χ_y = 0.773, **$N_{by,Rd}$ = 1308.39 kN**
flexural buckling around z-axis:
i_z = 41.2 mm, β_y = 1.00 (⊥ y-axis), $L_{cr,y}$ = 6.000 m, λ_1 = 81.745
λ_z = 1.780, z-buckling curve 'fire' ⇒ α_z = 0.65, Φ_z = 2.663, χ_z = 0.215, **$N_{bz,Rd}$ = 364.66 kN**

3.2.1.1. utilisations

Lk	N_d kN	U_y -	U_z -
1	136.50	**0.104**	**0.374**

3.2.2. lateral torsional buckling for bending around y-axis

c^2 = 103116 mm², buckling curve 'fire' ⇒ α_{LT} = 0.65, N_{cr} = 534.38 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 ⇒ $W_{pl,y}$	193.57	1.227	1.000	1.652	0.363	0.363	71.50	105.74	**0.676**

3.2.3. interaction

Lk	eqn.	μ_y -	k_y -	μ_{LT} -	k_{LT} -	U -
1	(4.21a)	-0.091	1.010	---	---	0.352
	(4.21b)	---	---	0.197	0.926	**1.000**

max U = 1.000 ≤ 1 ok

4. final result

maximum utilisation U = 1.000 ≤ 1 ok

verification succeeded

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
	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