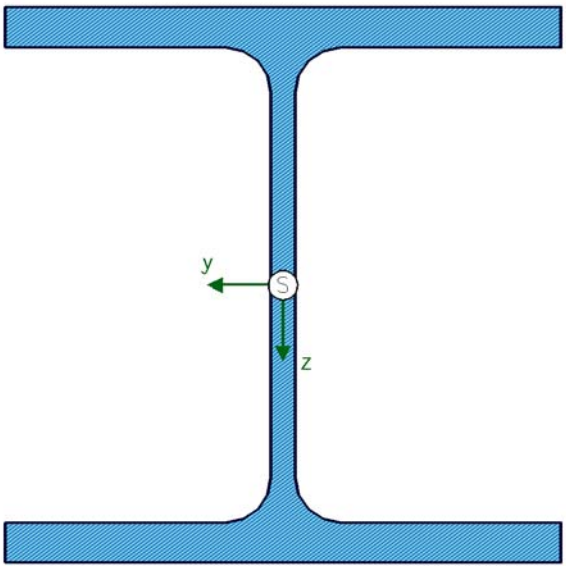
verification of stability EC 3-1-2 (12.10), NA: Deutschland 4H-EC3ST version: 12/2021-1b

1. input data

1.1. general information
verifications of stability in case of fire acc. to EN 1993-1-2
flexural buckling with the method of fictitious bars, no buckling direction

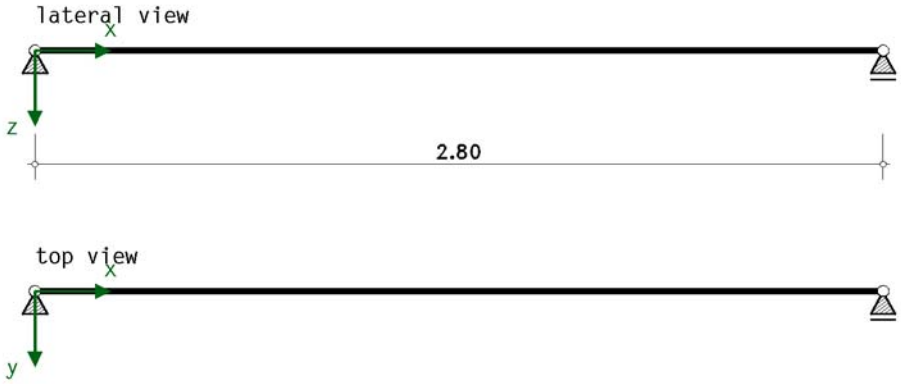
1.2. safety factor of material
resistance of cross-sections γ_{M0} = 1.00
resistance of members in stability failure γ_{M1} = 1.10
resistance of components in the event of fire $\gamma_{M,fi}$ = 1.00

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: HE220B
section scale 1:3.0



1.4. cross-section values (related to the centre of gravity S)
I_y = 8090.0 cm^4, I_z = 2840.0 cm^4, I_ζ = 8090.0 cm^4, I_η = 2840.0 cm^4, α = 0.0°
I_ω = 295400.0 cm^6, I_T = 76.8 cm^4
W_y = 736.0 cm^3, W_z = 258.0 cm^3, $W_{pl,y}$ = 827.0 cm^3, $W_{pl,z}$ = 394.0 cm^3
$z_{m,y}$ = 0.0 mm, $z_{m,z}$ = -0.0 mm, A = 91.0 cm^2

1.5. static system
all bearings with fork restraint, bar length 2.800 [m]
no intermediate bearing in z-direction, no intermediate bearing in y-direction



1.6. buckling coefficients

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

1.7. design member forces (load combinations)

Lk	N_d kN
1	980.00

N_d: constant axial force in the bar

1.8. fire design

thermal action due to the standard curve, fire resistance time t = 101.0 min
section all sides flamed
thermal insulation protection by Gipskarton-plated structures:
thermal conductivity λ_p = 0.20 W/(m·K), specific heat capacity c_p = 1700 J/(kg·K), maximum density ρ_p = 800 kg/m³
moisture content p_p = 20.0 %
thickness of insulating material d_p = 20.0 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 box A_p = 880.0 mm²/mm
section factor of the protected component A_p/V = 880.0 / 9104.1 ·10³ = 96.7 1/m
time saving due to moisture content of insulating material $t_v = (p_p \cdot \rho_p \cdot d_p^2)/(5 \cdot \lambda_p)$ = 6.4 min
cross-section temperature acc. to t = 101.0 min: **T_a = 567.5 °C**
reduction factors: $k_{y,fi}$ = 0.571, $k_{E,fi}$ = 0.404
material parameters: $f_{y,fi}$ = 134.1 N/mm², E_{fi} = 84895.7 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	87.3	16.0	5.45	0.850	107.69	107.69	single 1/1	---	---	---	1
2	87.3	16.0	5.45	0.850	107.69	107.69	single 1/1	---	---	---	1
3	152.0	9.5	16.00	0.850	107.69	107.69	both 2/1	---	---	---	1
4	87.3	16.0	5.45	0.850	107.69	107.69	single 1/1	---	---	---	1
5	87.3	16.0	5.45	0.850	107.69	107.69	single 1/1	---	---	---	1

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. flexural buckling around z-axis

I_p = 10930 cm⁴, I_T = 77 cm⁴, i_p^2 = 12011 mm, c^2 = 4666 mm², i_m^2 = 12011 mm²
i_z = 55.9 mm, β_y = 0.50 (⊥ y-axis), $L_{cr,y}$ = 1.400 m, λ_1 = 79.037
λ_z = 0.317, z-buckling curve 'fire' ⇒ α_z = 0.65, Φ_z = 0.653, χ_z = 0.817, **$N_{bz,Rd}$ = 996.78 kN**

3.2.1. utilisations

Lk	N_d kN	U_z -
1	980.00	**0.983**

max U = 0.983 < 1 ok

4. final result

maximum utilisation U = 0.983 < 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	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