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

1. input data

1.1. general information

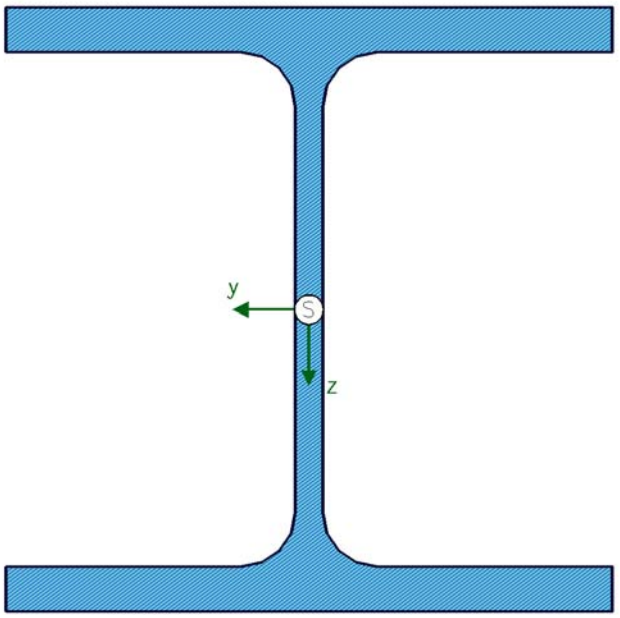
verifications of stability in case of fire acc. to EN 1993-1-2
lateral torsional buckling with the method of fictitious bars for N+My, interaction proof only with eqn. (4.21a,c)

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: HE200B
section scale 1:2.5



1.4. cross-section values (related to the centre of gravity S)

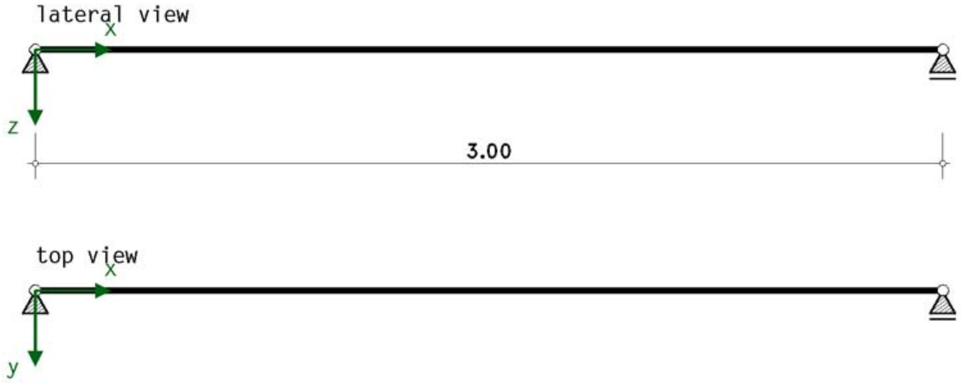
I_y = 5700.0 cm^4, I_z = 2000.0 cm^4, I_ζ = 5700.0 cm^4, I_η = 2000.0 cm^4, α = 0.0°
I_ω = 171100.0 cm^6, I_T = 59.5 cm^4
W_y = 570.0 cm^3, W_z = 200.0 cm^3, $W_{pl,y}$ = 643.0 cm^3, $W_{pl,z}$ = 306.0 cm^3
$z_{m,y}$ = 0.0 mm, $z_{m,z}$ = 0.0 mm, A = 78.1 cm^2, cross-section is torsionally soft

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 -
1	800.00	2	50.00	-1.000	0.602	2.555

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 = 15.2 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 = 1151.1 mm²/mm
section factor of the unprotected component A_m/V = 1151.1 / 7808.1 ·10³ = 147.4 1/m
fire-stressed inner surface of the enclosing box A_b = 800.0 mm²/mm
section factor for the enclosing box A_b/V = 800.0 / 7808.1 ·10³ = 102.5 1/m
correction factor k_{sh} = (A_b/V) / (A_m/V) = 102.5 / 147.4 = 0.695, I-section: 0.9·k_{sh} = 0.625
cross-section temperature acc. to t = 15.2 min: **T_a = 552.5 °C**
reduction factors: $k_{y,fi}$ = 0.617, $k_{E,fi}$ = 0.448
material parameters: $f_{y,fi}$ = 145.1 N/mm², E_{fi} = 94038.1 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	77.5	15.0	5.17	0.850	183.57	183.57	single 1/1	---	---	---	1
2	77.5	15.0	5.17	0.850	183.57	183.57	single 1/1	---	---	---	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	21.29	21.29	single 1/1	---	---	---	1
5	77.5	15.0	5.17	0.850	21.29	21.29	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. 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, β_z = 0.50 (⊥ z-axis), $L_{cr,z}$ = 1.500 m, λ_1 = 79.987
λ_y = 0.220, y-buckling curve 'fire' ⇒ α_y = 0.65, Φ_y = 0.595, χ_y = 0.870, **$N_{by,Rd}$ = 986.11 kN**
flexural buckling around z-axis:
i_z = 50.6 mm, β_y = 0.50 (⊥ y-axis), $L_{cr,y}$ = 1.500 m, λ_1 = 79.987
λ_z = 0.371, z-buckling curve 'fire' ⇒ α_z = 0.65, Φ_z = 0.689, χ_z = 0.787, **$N_{bz,Rd}$ = 892.04 kN**

3.2.1.1. utilisations

Lk	N_d kN	U_y -	U_z -
1	800.00	**0.811**	**0.897**

3.2.2. lateral torsional buckling for bending around y-axis

c^2 = 4747 mm^2, buckling curve 'fire' ⇒ α_{LT} = 0.65, N_{cr} = 8249.95 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 ⇒ $W_{pl,y}$	1452.04	0.253	1.000	0.614	0.852	0.852	50.00	79.43	**0.629**

3.2.3. interaction proof only with eqn. (4.21a,c)

Lk	eqn.	μ_y -	k_y -	μ_{LT} -	k_{LT} -	U -
1	(4.21a)	0.800	0.351	---	---	**0.999**

max U = 0.999 < 1 ok

4. final result

maximum utilisation U = 0.999 < 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