1 Prague Trade Centre

2 Standard

Calculation standard EN 1993-1-2
Calculation in accordance with Czech national annex.
Fire reliability factor $\gamma_{M,fi}$ = 1,000

3 Member 1

3.1 Input data

Length: 8,730 m

Section

Sector no.	Start [m]	End [m]	Section	Rotation [°]
1	0,000	8,730	HE 200 B	0,0

BARS OF CROSS-SECTION HEB - HE 200 B	
Cross-section dimension	
cross-section height	h = 200,0 mm
top flange width	b_{ft} = 200,0 mm
bottom flange width	b_{fb} = 200,0 mm
stem thickness	t_w = 9,0 mm
top flange thickness	t_{ft} = 15,0 mm
bottom flange thickness	t_{fb} = 15,0 mm
radius between stem and flanges	R_1 = 18,0 mm
Cross-sectional characteristics	
cross-sectional area	A = 7,810E+03 mm^2
distance of centroid from left edge of min. cross-section envelope	y_{cg} = 100,0 mm
distance of centroid from bottom edge of min. cross-section envelope	z_{cg} = 100,0 mm
moment of inertia w.r.t. horizontal centroidal axis	I_y = 5,700E+07 mm^4
moment of inertia w.r.t. vertical centroidal axis	I_z = 2,000E+07 mm^4
radius of gyration normal to horizontal centroidal axis	i_y = 85,4 mm
radius of gyration normal to vertical centroidal axis	i_z = 50,6 mm
rigidity moment in simple torsion	I_k = 5,960E+05 mm^4
Sectional parameters	
y-coordinate of shear center in centroidal coordinate system	y_{sc} = 0,0 mm
z-coordinate of shear center in centroidal coordinate system	z_{sc} = 0,0 mm
sectorial moment of inertia w.r.t. shear center	$I_{w.s}$ = 1,710E+11 mm^6

Material

Name: EN 10025 : Fe 360
Material characteristics:

Elastic modulus	E :	210000	MPa
Shear modulus	G :	81000	MPa
Yield strength	f_y :	235,0	MPa
Ultimate strength	f_u :	360,0	MPa

Fire detail

Count of fire detail sectors: 3

Detail at sector no.1 0,000m-2,000m:
Cross-section protected by spray, exposed to fire on all sides
Fire protection material: Spray-coatings - vermiculite

Thickness	d_p	:	8,5	mm
Density	ρ_p	:	350,0	kg/m^3
Heat capacity	c_p	:	1200,0	J/kg/K
Thermal conduction	λ_p	:	0,120	W/m/K

Detail at sector no.2 2,000m-7,000m:
Cross-section covered by board, exposed to fire on all sides
Fire protection material: Boards - silicate (calcium silicate) fibres and cement

Thickness	d_p	:	10,0	mm
Density	ρ_p	:	800,0	kg/m^3
Heat capacity	c_p	:	1200,0	J/kg/K
Thermal conduction	λ_p	:	0,150	W/m/K

Detail at sector no.3 7,000m-8,730m:
Cross-section protected by spray, exposed to fire on all sides
Fire protection material: Spray-coatings - vermiculite

Thickness	d_p	:	8,5	mm
Density	ρ_p	:	350,0	kg/m^3
Heat capacity	c_p	:	1200,0	J/kg/K
Thermal conduction	λ_p	:	0,120	W/m/K

Temperature curve

Standard temperature curve

Load - internal forces

Total number of loads: 2

Load 1: compression + bending:

	N[kN]	V_3[kN]	M_2[kNm]	V_2[kN]	M_3[kNm]	T_t[kNm]	T_ω[kNm]	B[kNm^2]
Max. value	0,000	30,000	26,000	0,000	0,000	0,000	0,000	0,000
Min. value	-82,000	-30,000	0,000	0,000	0,000	0,000	0,000	0,000

Load 2: tension:

	N[kN]	V_3[kN]	M_2[kNm]	V_2[kN]	M_3[kNm]	T_t[kNm]	T_ω[kNm]	B[kNm^2]
Max. value	330,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Min. value	330,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000

Load 1: compression + bending:

X[m]	N[kN]	V_3[kN]	M_2[kNm]	V_2[kN]	M_3[kNm]	T_t[kNm]	T_ω[kNm]	B[kNm^2]
0,000	-82,000	30,000	0,000	0,000	0,000	0,000	0,000	0,000
4,365		30,000						
4,365		-30,000	26,000					
8,730	-82,000	-30,000	0,000	0,000	0,000	0,000	0,000	0,000

Load 2: tension:

X[m]	N[kN]	V_3[kN]	M_2[kNm]	V_2[kN]	M_3[kNm]	T_t[kNm]	T_ω[kNm]	B[kNm^2]
0,000	330,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
8,730	330,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000

Buckling

Buckling perpendicular to z:

Sector no.	Start [m]	End [m]	Length for buckling [m]	Buckling length factor k_z	Buckling length $L_{cr,z}$ [m]
1	0,000	4,365	4,365	1,000	4,365
2	4,365	8,730	4,365	1,000	4,365

Buckling perpendicular to y:

Sector no.	Start [m]	End [m]	Length for buckling [m]	Buckling length factor k_y	Buckling length $L_{cr,y}$ [m]
1	0,000	4,365	4,365	1,000	4,365
2	4,365	8,730	4,365	1,000	4,365

LTB

Lat. tors. buckling due to b. moment M_y:

Sector no.	Start [m]	End [m]	l_{z1} = [m]	Moment area shape	Load position
1	0,000	8,730	8,730	Constant bending moment distribution	-

Lat. tors. buckling due to b. moment M_z:

Sector no.	Start [m]	End [m]	l_{y1} = [m]	Moment area shape	Load position
1	0,000	8,730	8,730	Constant bending moment distribution	-

3.2 Results

Intermediate results

Load no.1:
Fire check:
Factors of member action during fire:
κ_1 = 1,000 κ_2 = 1,000
Critical temperature: 659,5°C
Member temperature development:
Bulk density of steel ρ = 7,850E+03 kg/m^3
Section factor A_p/V = 147,388 m^{-1}
Thermal conductivity of fire protective material λ_p = 0,1 W/m/K
Specific heat of fire protection material c_p = 1200,0 J/kg/K
Bulk density of fire protection material ρ_p = 3,500E+02 kg/m^3
Fire protection material thickness d_p = 8,5 mm
Specific heat of steel changes
from 439,8 J/kg/K at 20,0°C
to 828,7 J/kg/K at 660,8°C
Fire resistance period: 61,5 min > 60,0 min
Fire resistance is sufficient

Cross-section check at steel temperature 652,6°C
Reduction factors of material properties :
k_y = 0,344

k_E = 0,215

Cross-section classification:

ε = 0,850 × √(235,0 / f_y) = 0,850 × √(235,0 / 235,0) = 0,850

Web classification:
c = 134,0 mm
t = 9,0 mm
c/t = 14,9; 14,9 < 28,0; Class 1

Top flange left part classification:
c = 77,5 mm
t = 15,0 mm
c/t = 5,2; 5,2 < 7,6; Class 1

Top flange right part classification:
c = 77,5 mm
t = 15,0 mm
c/t = 5,2; 5,2 < 7,6; Class 1

Bottom flange left part classification:
c = 77,5 mm
t = 15,0 mm
c/t = 5,2; 5,2 < 7,6; Class 1

Bottom flange right part classification:
c = 77,5 mm
t = 15,0 mm
c/t = 5,2; 5,2 < 7,6; Class 1

Cross-section class 1

Calculation of shear resistance in z-axis direction

Shear area $A_{v,z}$ = 2,485E03 mm^2
Cross-section shear resistance $V_{pl,Rd,z}$ = 115,935 kN
Shear buckling resistance:
d/t_w = 14,9 < 69,0
Web buckling has not to be checked
Shear buckling resistance $V_{ba,Rd,z}$ = 115,935 kN
Design shear resistance $V_{Rd,z}$ = 115,935 kN

Calculation of shear res. in y-axis direction

Shear area $A_{v,y}$ = 5,325E03 mm^2
Cross-section shear resistance $V_{pl,Rd,y}$ = 248,432 kN

Buckling resistance calculation

V_z <= 0.5 *115,935 kN
V_y <= 0.5 *248,432 kN
λ_1 = 93,9
Buckling perpendicular to z:
Buckling length $L_{cr,z}$ = 4,365 m
Slenderness λ_z = 86,3
Relative slenderness $\lambda_{bar,z}$ = 1,160
Imperfection factor α = 0,650
φ_z = 1,551
Buckling factor χ_z = 0,388
Design buckling resistance $N_{b,Rd,z}$ = 244,724 kN
Buckling perpendicular to y:
Buckling length $L_{cr,y}$ = 4,365 m
Slenderness λ_y = 51,1
Relative slenderness $\lambda_{bar,y}$ = 0,687
Imperfection factor α = 0,650
φ_y = 0,960

Buckling factor χ_y = 0,614
Design buckling resistance $N_{b,Rd,y}$ = 387,335 kN
244,724 < 387,335 Design buckling resistance $N_{b,Rd}$ = 244,724 kN

B. moment resistance calculation from M_y
V_z <= 0.5 *115,935 kN
V_y <= 0.5 *248,432 kN
Plastic section modulus $W_{pl,y}$ = 6,425E05 mm^3
Cross-section b. moment resistance $M_{c,Rd,y}$ = 51,922 kNm
Design b. moment resistance $M_{c,Rd,y}$ = 51,922 kNm
Buckling effect calculation:
Laterally restrained point spacing L_{z1} = 8,730 m
Buckling length factors: k = 1,000; k_w = 1,000
z_j = 0,0 mm
Dimensionless torsion parameter: κ_{wt} = 0,310
Dimensionless parameter of load application point with respect to shear center : ζ_g = 0,000
Dimensionless cross-section asymmetry parameter: ζ_j = 0,000
Cross-section asymmetry parameter: ψ_f = 0,000
Load & support condition factors:
C_1 = 1,000; C_2 = 0,000; C_3 = 1,000
Dimensionless critical bending moment: μ_{cr} = 1,047
El. crit. bending moment M_{cr} = 169,667 kNm
Rel. slenderness $\lambda_{bar,LT}$ = 1,192
Imperfection factor α = 0,650
φ = 1,598
Transverse and torsion stability factor $\chi_{LT,y}$ = 0,376
Buckling b. moment resistance $M_{b,Rd,y}$ = 19,507 kNm

B. moment M_z resistance calculation
V_z <= 0.5 *115,935 kN
V_y <= 0.5 *248,432 kN
Plastic section modulus $W_{pl,z}$ = 3,058E05 mm^3
Cross-section b. moment resistance $M_{c,Rd,z}$ = 24,712 kNm
Design b. moment resistance $M_{c,Rd,z}$ = 24,712 kNm

Shear capacity check

Magnitude	Load	Resistance	Utilization	
V_z	30,000 kN	115,935 kN	25,9 %	Pass
V_y	0,000 kN	248,432 kN	0,0 %	Pass

Axial force and bending moment combination check
Critical combination check: buckling compression and lateral torsional buckling:
Check of buckling Y:
| 0,212 + 0,611 + 0,000 | < 1
0,822 < 1 ==> Pass
Check of buckling Z :
| 0,335 + 0,611 + 0,000 | < 1
0,946 < 1 ==> Pass

Load no.2:
Fire check:
Factors of member action during fire:
κ_1 = 1,000 κ_2 = 1,000

Critical temperature: 741,8°C
Member temperature development:
Bulk density of steel ρ = 7,850E+03 kg/m^3
Section factor A_p/V = 147,388 m^{-1}
Thermal conductivity of fire protective material λ_p = 0,1 W/m/K
Specific heat of fire protection material c_p = 1200,0 J/kg/K
Bulk density of fire protection material ρ_p = 3,500E+02 kg/m^3
Fire protection material thickness d_p = 8,5 mm
Specific heat of steel changes
from 439,8 J/kg/K at 20,0°C
to 2325,0 J/kg/K at 741,9°C
Fire resistance period: 88,5 min > 60,0 min
Fire resistance is sufficient

Cross-section check at steel temperature 652,6°C
Reduction factors of material properties :
k_y = 0,344
k_E = 0,215
Cross-section classification:
ε = 0,850 × √(235,0 / f_y) = 0,850 × √(235,0 / 235,0) = 0,850
Web classification:
c = 134,0 mm
t = 9,0 mm
c/t = 14,9; 14,9 < 28,0; Class 1
Top flange left part classification:
c = 77,5 mm
t = 15,0 mm
c/t = 5,2; 5,2 < 7,6; Class 1
Top flange right part classification:
c = 77,5 mm
t = 15,0 mm
c/t = 5,2; 5,2 < 7,6; Class 1
Bottom flange left part classification:
c = 77,5 mm
t = 15,0 mm
c/t = 5,2; 5,2 < 7,6; Class 1
Bottom flange right part classification:
c = 77,5 mm
t = 15,0 mm
c/t = 5,2; 5,2 < 7,6; Class 1
Cross-section class 1

Calculation of shear resistance in z-axis direction
Shear area $A_{v,z}$ = 2,485E03 mm^2
Cross-section shear resistance $V_{pl,Rd,z}$ = 115,935 kN
Shear buckling resistance:
d/t_w = 14,9 < 69,0
Web buckling has not to be checked
Shear buckling resistance $V_{ba,Rd,z}$ = 115,935 kN
Design shear resistance $V_{Rd,z}$ = 115,935 kN

Calculation of shear res. in y-axis direction
Shear area $A_{v,y}$ = 5,325E03 mm^2
Cross-section shear resistance $V_{pl,Rd,y}$ = 248,432 kN

Calc. of resistance in tension
V_z <= 0.5 *115,935 kN

V_y <= 0.5 *248,432 kN
Design resistance in tension at temperature T $N_{t,Rd}$ = 631,102 kN

B. moment resistance calculation from M_y
V_z <= 0.5 *115,935 kN
V_y <= 0.5 *248,432 kN
Plastic section modulus $W_{pl,y}$ = 6,425E05 mm^3
Cross-section b. moment resistance $M_{c,Rd,y}$ = 51,922 kNm
Design b. moment resistance $M_{c,Rd,y}$ = 51,922 kNm

B. moment M_z resistance calculation
V_z <= 0.5 *115,935 kN
V_y <= 0.5 *248,432 kN
Plastic section modulus $W_{pl,z}$ = 3,058E05 mm^3
Cross-section b. moment resistance $M_{c,Rd,z}$ = 24,712 kNm
Design b. moment resistance $M_{c,Rd,z}$ = 24,712 kNm

Shear capacity check

Magnitude	Load	Resistance	Utilization	
V_z	0,000 kN	115,935 kN	0,0 %	Pass
V_y	0,000 kN	248,432 kN	0,0 %	Pass

Axial force and bending moment combination check
Critical combination check: simple tension and bending moment:
Check of buckling Y:
| 0,523 + 0,000 + 0,000 | < 1
0,523 < 1 ==> Pass

Overall check

Decisive load: Load 1: compression + bending
Cross-section class: 1
Critical temperature: 659,5°C
Fire resistance period: 61,5 min ≥ 60,0 min **Pass**
Check at time t = 60,0 min:
Gas temperature: 945,3°C Steel temperature: 652,6°C
Shear check due to shear force V_z:
30,000 kN < 115,935 kN **Pass**
Critical comination check - compression and b. moment:
Internal forces: N = -82,000 kN; M_y = 11,913 kNm; M_z = 0,000 kNm
Buckling Y: Resistances: N_R = -387,335 kN; $M_{y,R}$ = 19,507 kNm
| 0,212 + 0,611 + 0,000 | = | 0,822 | < 1 **Pass**
Buckling Z: Resistances: N_R = -244,724 kN; $M_{y,R}$ = 19,507 kNm
| 0,335 + 0,611 + 0,000 | = | 0,946 | < 1 **Pass**
Section ok