1 Prague Trade Centre

2 Standard

Calculation standard EN 1993-1-1
Calculation in accordance with Czech national annex.

Cross-section resistance factor	γ_{M0}	=	1,000
Stability check resistance factor	γ_{M1}	=	1,000
Perforated cross-section resistance factor	γ_{M2}	=	1,250

3 Beam B56

3.1 Input data

Length: 8,730 m

Section

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

BARS OF CROSS-SECTION I - I 200	
Cross-section dimension	
cross-section height	h = 200,0 mm
top flange width	b_{ft} = 90,0 mm
bottom flange width	b_{fb} = 90,0 mm
stem thickness	t_w = 7,5 mm
top flange thickness	t_{ft} = 11,3 mm
bottom flange thickness	t_{fb} = 11,3 mm
radius between stem and flanges	R_1 = 7,5 mm
radius of flange inner edges	R_2 = 4,5 mm
Cross-sectional characteristics	
cross-sectional area	A = 3,340E+03 mm^2
distance of centroid from left edge of min. cross-section envelope	y_{cg} = 45,0 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 = 2,140E+07 mm^4
moment of inertia w.r.t. vertical centroidal axis	I_z = 1,160E+06 mm^4
radius of gyration normal to horizontal centroidal axis	i_y = 80,0 mm
radius of gyration normal to vertical centroidal axis	i_z = 18,6 mm
rigidity moment in simple torsion	I_k = 1,360E+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	$I_{w.s}$ = 9,980E+09 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

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	20,000	14,000	0,000	0,000	0,000	0,000	0,000
Min. value	-55,000	-20,000	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	458,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Min. value	458,000	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	-55,000	20,000	0,000	0,000	0,000	0,000	0,000	0,000
4,365		20,000	14,000					
4,365		-20,000						
8,730	-55,000	-20,000	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	458,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
8,730	458,000	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	1,000	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	1,000	No input	-

Cross-section perforation

Cross-section perforation at sector no.1: Start X =2,000m; Length 0,200m

Number walls	No. of openings n	Opening diameter d [mm]	End spacing b [mm]	Opening distance a [mm]	Filled openings
1	1	60,0	100,0	0,0	NO

3.2 Results

Intermediate results

Cross-section classification:

ε = $\sqrt{(235,0 / f_y)}$ = $\sqrt{(235,0 / 235,0)}$ = 1,000

Web classification:

c = 162,4 mm
t = 7,5 mm
c/t = 21,7; 21,7 < 33,0; Class 1

Top flange left part classification:

c = 33,8 mm
t = 11,3 mm
c/t = 3,0; 3,0 < 9,0; Class 1

Top flange right part classification:

c = 33,8 mm
t = 11,3 mm
c/t = 3,0; 3,0 < 9,0; Class 1

Bottom flange left part classification:

c = 33,8 mm
t = 11,3 mm
c/t = 3,0; 3,0 < 9,0; Class 1

Bottom flange right part classification:

c = 33,8 mm
t = 11,3 mm
c/t = 3,0; 3,0 < 9,0; Class 1

Cross-section class 1

Calculation of shear res. in z-axis direction

Shear area $A_{v,z}$ = 1,560E03 mm^2
Cross-section shear resistance $V_{pl,Rd,z}$ = 211,691 kN
Shear buckling resistance:
d/t_w = 21,7 < 69,0
Web buckling has not to be checked
Shear buckling resistance $V_{ba,Rd,z}$ = 211,691 kN
Design shear resistance $V_{Rd,z}$ = 211,691 kN

Calculation of shear res. in y-axis direction

Shear area $A_{v,y}$ = 1,780E03 mm^2
Cross-section shear resistance $V_{pl,Rd,y}$ = 241,472 kN

Buckling resistance calculation

V_z <= 0.5 *211,691 kN
V_y <= 0.5 *241,472 kN
λ_1 = 93,9
Buckling perpendicular to z:
Buckling length $L_{cr,z}$ = 4,365 m
Slenderness λ_z = 234,2
Relative slenderness $\lambda_{bar,z}$ = 2,494
Buckling curve: b, imperfection factor α = 0,340
φ_z = 4,000

Buckling factor χ_z = 0,140
Design buckling resistance $N_{b,Rd,z}$ = 110,123 kN
Buckling perpendicular to y:
Buckling length $L_{cr,y}$ = 4,365 m
Slenderness λ_y = 54,5
Relative slenderness $\lambda_{bar,y}$ = 0,581
Buckling curve: a, imperfection factor α = 0,210
φ_y = 0,709
Buckling factor χ_y = 0,897
Design buckling resistance $N_{b,Rd,y}$ = 704,193 kN
110,123 < 704,193 Design buckling resistance $N_{b,Rd}$ = 110,123 kN

B. moment M_y resistance calculation
V_z <= 0.5 *211,691 kN
V_y <= 0.5 *241,472 kN
Plastic section modulus $W_{pl,y}$ = 2,481E05 mm^3
Cross-section b. moment resistance $M_{c,Rd,y}$ = 58,299 kNm
Design b. moment resistance $M_{c,Rd,y}$ = 58,299 kNm
Buckling effect calculation:
Laterally restrained point spacing L_{z1} = 1,000 m
Buckling length factors: k = 1,000; k_w = 1,000
z_j = 0,0 mm
Dimensionless torsion parameter: κ_{wt} = 1,370
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} = 1,696
El. crit. bending moment M_{cr} = 276,072 kNm
Rel. slenderness $\lambda_{bar,LT}$ = 0,460
Reduction factor determination $\chi_{LT,y}$ from buckling curve b:
Imperfection factor α = 0,340
φ = 0,650
Transverse and torsion stability factor $\chi_{LT,y}$ = 0,902
Buckling b. moment resistance $M_{b,Rd,y}$ = 52,569 kNm

B. moment M_z resistance calculation
V_z <= 0.5 *211,691 kN
V_y <= 0.5 *241,472 kN
Plastic section modulus $W_{pl,z}$ = 4,310E04 mm^3
Cross-section b. moment resistance $M_{c,Rd,z}$ = 10,130 kNm
Design b. moment resistance $M_{c,Rd,z}$ = 10,130 kNm

Shear capacity check

Magnitude	Load	Capacity	Utilization	
V_z	20,000 kN	211,691 kN	9,4 %	Pass
V_y	0,000 kN	241,472 kN	0,0 %	Pass

Axial force and bending moment combination check
Critical combination check: buckling compression and lateral torsional buckling:
Check of buckling Y:

| 0,078 + 0,266 + 0,000 | < 1
0,344 < 1 ==> Pass
Check of buckling Z :
| 0,499 + 0,266 + 0,000 | < 1
0,766 < 1 ==> Pass

Slenderness check
Calculated member slenderness: 234,2
Limit member slenderness: 250,0
Slenderness sufficient
Cross-section classification:
ε = $\sqrt{}$(235,0 / f_y) = $\sqrt{}$(235,0 / 235,0) = 1,000
Web classification:
c = 162,4 mm
t = 7,5 mm
c/t = 21,7; 21,7 < 33,0; Class 1
Top flange left part classification:
c = 33,8 mm
t = 11,3 mm
c/t = 3,0; 3,0 < 9,0; Class 1
Top flange right part classification:
c = 33,8 mm
t = 11,3 mm
c/t = 3,0; 3,0 < 9,0; Class 1
Bottom flange left part classification:
c = 33,8 mm
t = 11,3 mm
c/t = 3,0; 3,0 < 9,0; Class 1
Bottom flange right part classification:
c = 33,8 mm
t = 11,3 mm
c/t = 3,0; 3,0 < 9,0; Class 1
Cross-section class 1

Calculation of shear res. in z-axis direction
Shear area $A_{v,z}$ = 1,560E03 mm^2
Cross-section shear resistance $V_{pl,Rd,z}$ = 211,691 kN
Shear buckling resistance:
d/t_w = 21,7 < 69,0
Web buckling has not to be checked
Shear buckling resistance $V_{ba,Rd,z}$ = 211,691 kN
Design shear resistance $V_{Rd,z}$ = 211,691 kN

Calculation of shear res. in y-axis direction
Shear area $A_{v,y}$ = 1,780E03 mm^2
Cross-section shear resistance $V_{pl,Rd,y}$ = 241,472 kN

Calc. of resistance in tension
V_z <= 0.5 *211,691 kN
V_y <= 0.5 *241,472 kN
Design resistance in tesion $N_{t,Rd}$ = 784,900 kN

B. moment M_y resistance calculation
V_z <= 0.5 *211,691 kN
V_y <= 0.5 *241,472 kN
Plastic section modulus $W_{pl,y}$ = 2,481E05 mm^3
Cross-section b. moment resistance $M_{c,Rd,y}$ = 58,299 kNm

Design b. moment resistance $M_{c,Rd,y}$ = 58,299 kNm

B. moment M_z resistance calculation

V_z <= 0.5 *211,691 kN
V_y <= 0.5 *241,472 kN
Plastic section modulus $W_{pl,z}$ = 4,310E04 mm^3
Cross-section b. moment resistance $M_{c,Rd,z}$ = 10,130 kNm
Design b. moment resistance $M_{c,Rd,z}$ = 10,130 kNm

Shear capacity check

Magnitude	Load	Capacity	Utilization	
V_z	0,000 kN	211,691 kN	0,0 %	Pass
V_y	0,000 kN	241,472 kN	0,0 %	Pass

Axial force and bending moment combination check
Critical combination check: simple tension and bending moment:
Check of buckling Y:
| 0,584 + 0,000 + 0,000 | < 1
0,584 < 1 ==> Pass

Slenderness check
Calculated member slenderness: 234,2
Limit member slenderness: 250,0
Slenderness sufficient

Overall check

Decisive load: Load 1: compression + bending
Cross-section class: 1
Shear check due to shear force V_z:
20,000 kN < 211,691 kN **Pass**
Internal forces: N = -55,000 kN; M_y = 14,000 kNm; M_z = 0,000 kNm
Critical combination check: buckling compression and bending moment:
Buckling Y: Resistances: N_R = -704,193 kN; $M_{y,R}$ = 52,569 kNm
| 0,078 + 0,266 + 0,000 | = | 0,344 | < 1 **Pass**
Buckling Z: Resistances: N_R = -110,123 kN; $M_{y,R}$ = 52,569 kNm
| 0,499 + 0,266 + 0,000 | = | 0,766 | < 1 **Pass**

Member slenderness check:
member slenderness: 234,2
limit slenderness: 250,0
Member slenderness ok

Section ok

Utilization

Section utilization: 76,6 %