Column reinforcement

Structural member: Beam 8

Verification for eccentric axial force

Materials

Concrete **C25/30** f_{ck} = 25 MPa Rebar steel **B500B** f_{yk} = 500 MPa

Buckling parameters

Clear height of the member: l = 3,000 m

Factor depending on the support conditions		The effective length
Hinged - Hinged	$\beta_{yy} = 1$	$l_{0,y} = \beta_{yy} \cdot l = 1 \cdot 3{,}000 = 3{,}000$ m
Cantilever	$\beta_{zz} = 2$	$l_{0,z} = \beta_{zz} \cdot l = 2 \cdot 3{,}000 = 6{,}000$ m

Column cross-section parameters

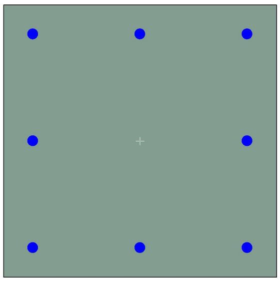
Cross-section dimensions:

$h_y = b_y = 40{,}0$ cm $h_z = b_z = 40{,}0$ cm

The area of concrete cross section:

$A_c = b_y \cdot h_z = 40{,}0 \cdot 40{,}0 = 1600$ cm²

Concrete cover of the longitudinal reinforcement: c = 3,5 cm



Reinforcement parameters

Name: **oszlop**

$8\phi16$ (A_s = 16,08 cm²)

Checking detailing rules EN 1992-1-1 9.5

Checking ratio of column cross-section dimensions h and b .: EN 1992-1-1 9.5.1 (1)

h = 40 cm < $4 \cdot b = 4 \cdot 40 = 160$ cm ✔

Load case: **[1,35*G] {1,5*0,7*Q1} (1,5*0,7*Q2+1,5*0,7*Q3+1,5*0,7*Q4+1,5*0,7*Q5+1,5*0,6*Wind+1,5*0,7*Q6)**

N_{Ed} = 1374,8 kN

The minimum area of longitudinal reinforcement: EN 1992-1-1 9.5.3 (2) (9.12N)

$$A_{s,min} = \text{Max}\left(\frac{0{,}1 \cdot N_{Ed}}{f_{yd}} = \frac{0{,}1 \cdot 1374{,}8}{434{,}783} = 3{,}16\ ;\ 0{,}002 \cdot A_c = 0{,}002 \cdot 1600 = 3{,}20\right) = 3{,}20 \text{ cm}^2 < A_s = 16{,}08 \text{ cm}^2$$ ✔

The maximum area of longitudinal reinforcement: 9.5.3 (3)

$A_{s,max} = 0{,}04 \cdot A_c = 0{,}04 \cdot 1600 = 64{,}00$ cm² > A_s = 16,08 cm² ✔

The maximum spacing of the transverse reinforcement along the column: 9.5.3 (3)

$s_{cl,tmax} = \min(20 \cdot \phi_{prov,min}\ ;\ b\ ;\ 40) = \min(20 \cdot 1{,}6\ ;\ 40\ ;\ 40) = 32$ cm > s_w = 50 mm ✔

In sections within a distance of h = 40 cm above or below a beam or slab stirrup spacing should not exceed the following value

$0{,}6 \cdot s_{cl,tmax} = 0{,}6 \cdot 32 = 19{,}2$ cm > s_w = 50 mm ✔

Detailing rules to ensure local ductility EN 1998-1 5.4.3.2.2.

The minimum area of longitudinal reinforcement: EN 1998-1 5.4.3.2.2. (1)P

$A_{sl,min} = A_c \cdot \rho_{l,min} = 1600 \cdot 0{,}01 = 16 \text{ cm}^2 < A_s = 16{,}08 \text{ cm}^2$ ✔

The minimum area of longitudinal reinforcement: EN 1998-1 5.4.3.2.2. (1)P

$A_{sl,max} = A_c \cdot \rho_{l,max} = 1600 \cdot 0{,}04 = 64 \text{ cm}^2 > A_s = 16{,}08 \text{ cm}^2$ ✔

The minimum stirrup diameter: EN 1998-1 5.4.3.2.2. (10)P

$d_{bw,min} = 6 \text{ mm} < \phi_w = 10 \text{ mm}$ ✔

The concrete cover for stirrups: $c_w = 25 \text{ mm}$

Width of the confined core (between the centerline of stirrups):

$b_o = b - 2 \cdot c_w = 400 - 2 \cdot 25 = 350 \text{ mm}$

The maximum stirrup spacing: EN 1998-1 5.4.3.2.2. (4) (5.18)

$$s_{t,max} = \max\left(\frac{b_o}{2} \;;\; 175 \;;\; 8 \cdot d_{bL}\right) = \max\left(\frac{350}{2} \;;\; 175 \;;\; 8 \cdot 16\right) = 128 \text{ mm} > s_w = 50 \text{ mm}$$ ✔

Design values of material properties

$$f_{cd} = \alpha_{cc} \cdot \frac{f_{ck}}{\gamma_c} = 1 \cdot \frac{25}{1{,}5} = 16{,}6667 \text{ MPa} = 16666{,}7 \text{ KPa}$$ EN 1992-1-1 3.1.6. (1)P (3.15)

$$f_{yd} = \frac{f_{yk}}{\gamma_s} = \frac{500}{1{,}15} = 434{,}783 \approx 435 \text{ MPa} = 435000 \text{ KPa}$$ EN 1992-1-1 3.2.7. (2) Fig. 3.8

Column forces in the critical section

Load case: **[G] {±FR1 3} (0,3*Q1+0,3*Q2+0,3*Q3+0,3*Q4+0,3*Q5+0,3*Q6)**

$N_{Ed,0} = 892{,}054 \text{ kN}$ $M_{Ed,0y} = -32{,}1395 \text{ kNm}$ $M_{Ed,0z} = 53{,}1876 \text{ kNm}$

Initial eccentricity:

$$e_{e,x,y} = \frac{M_{Ed,0z}}{N_{Ed,0}} = \frac{53{,}1876}{892{,}054} = 0{,}0596238 \text{ m} \qquad e_{e,x,z} = \frac{M_{Ed,0y}}{N_{Ed,0}} = \frac{(-32{,}1395)}{892{,}054} = -0{,}0360287 \text{ m}$$

Eccentricity due to geometrical imperfections

The equivalent inclination representing imperfection: EN 1992-1-1 5.2. (5)

$\Theta_i = \Theta_0 \cdot \alpha_h \cdot \alpha_m = 0{,}005 \cdot 1 \cdot 1 = 0{,}005$ EN 1992-1-1 (5.1)

where:

The reduction factor for height:

$$\alpha_h = \frac{2}{\sqrt{l}} = \frac{2}{\sqrt{3{,}000}} = 1{,}1547 > 1 \rightarrow \alpha_h = 1$$

The reduction factor for number of members:

$$\alpha_m = \sqrt{0{,}5 \cdot \left(1 + \frac{1}{m}\right)} = \sqrt{0{,}5 \cdot \left(1 + \frac{1}{1}\right)} = 1$$

The number of vertical members contributing to the total effect :

$m = 1$

Equivalent eccentricity representing imperfections:

$e_{iy} = \Theta_i \cdot \frac{l_{0,z}}{2} = 0{,}005 \cdot \frac{6{,}000}{2} = 0{,}015 \text{ m}$ $e_{iz} = \Theta_i \cdot \frac{l_{0,y}}{2} = 0{,}005 \cdot \frac{3{,}000}{2} = 0{,}0075 \text{ m}$ EN 1992-1-1 (5.1)

Eccentricity due to geometrical imperfections

	Cantilever	Hinged - Hinged
at the bottom end	$e_{i,1y} = e_{iy} = 0{,}015$ m	$e_{i,1z} = e_{iz} = 0{,}0075$ m
at the top end	$e_{i,2y} = 0$ m	$e_{i,2z} = e_{iz} = 0{,}0075$ m
at the position of verification	$e_{i,x,y} = e_{i,1y} = 0{,}015$ m	$e_{i,x,z} = e_{iz} = 0{,}0075$ m

Slenderness criterion for isolated members

Slenderness limit: EN 1992-1-1 (5.13N)

$\lambda_{limy} = \frac{20 \cdot A_y \cdot B \cdot C_y}{\sqrt{n}} = \frac{20 \cdot 0{,}71429 \cdot 1{,}2348 \cdot 1{,}3295}{\sqrt{0{,}33452}} = 40{,}549$ $\lambda_{limz} = \frac{20 \cdot A_z \cdot B \cdot C_z}{\sqrt{n}} = \frac{20 \cdot 0{,}71429 \cdot 1{,}2348 \cdot 1{,}5847}{\sqrt{0{,}33452}} =$

$= 48{,}332$

where: $A_y = \frac{1}{1 + 0{,}2 \cdot \phi_{efy}} = \frac{1}{1 + 0{,}2 \cdot 2} = 0{,}71429$ $A_z = \frac{1}{1 + 0{,}2 \cdot \phi_{efz}} = \frac{1}{1 + 0{,}2 \cdot 2} = 0{,}71429$

$B = \sqrt{1 + 2 \cdot \omega} = \sqrt{1 + 2 \cdot 0{,}26239} = 1{,}2348$

$C_y = 1{,}7 - r_{my} = 1{,}7 - 0{,}37049 = 1{,}3295$ $C_z = 1{,}7 - r_{mz} = 1{,}7 - 0{,}11533 = 1{,}5847$

$r_{my} = \frac{M_{02y}}{M_{01y}} = \frac{(-14{,}3861)}{(-38{,}8299)} = 0{,}37049$ $r_{mz} = \frac{M_{02z}}{M_{01z}} = \frac{7{,}6772}{66{,}5684} = 0{,}11533$

The slenderness ratio: EN 1992-1-1 (5.14)

$\lambda_y = \frac{l_{0,y}}{i_y} = \frac{3{,}000}{0{,}115} = 25{,}981 < \lambda_{limy} = 40{,}549$ ✔ $\lambda_z = \frac{l_{0,z}}{i_z} = \frac{6{,}000}{0{,}115} = 51{,}962 > \lambda_{limz} = 48{,}332$ ‼

The second order effects perpendicular to the y axis can be ignored.

Eccentricity due to second order effects

First order bending moment including the effect of imperfections:

$M_{0Edz} = M_{Ed01z} + N_{Ed} \cdot e_{iy} = 53{,}1876 + 892{,}054 \cdot 0{,}015 = 66{,}57 \text{ kNm}$ EN 1992-1-1 5.8.8.2. (1)

Method based on nominal curvature EN 1992-1-1 5.8.8.

The correction factor depending on axial load:

$k_r = \frac{n_u - n}{n_u - n_{bal}} = \frac{1{,}2624 - 0{,}33452}{1{,}2624 - 0{,}4} = 1{,}0759 > 1 \rightarrow k_r = 1$ EN 1992-1-1 (5.36)

The factor for taking account of creep: EN 1992-1-1 (5.37)

$k_{\phi z} = \max\,(1 + \beta_z \cdot \phi_{efz}\ ;\ 1) = \max\,(1 + 0{,}12859 \cdot 2\ ;\ 1) = 1{,}2572$

Curvature:

$\kappa_z = k_r \cdot k_{\phi z} \cdot \kappa_{0z} = 1 \cdot 1{,}2572 \cdot 0{,}014386 = 0{,}018086$ EN 1992-1-1 (5.34)

where:

$\kappa_{0z} = \frac{\varepsilon_{yd}}{0{,}45 \cdot d_z} = \frac{0{,}002175}{0{,}45 \cdot 0{,}335966} = 0{,}014386$

The nominal stiffness:

$EI_z = k_{cz} \cdot E_{cd} \cdot I_{cz} + k_s \cdot E_s \cdot I_{sz} = 0{,}038106 \cdot 26{,}2298 \cdot 213333 + 1 \cdot 2 \cdot 10^8 \cdot 2973{,}59 = 8079{,}45 \text{ kNm}^2$ EN 1992-1-1 (5.21)

The buckling load based on nominal stiffness:

$N_{bz} = \pi^2 \cdot \frac{EI_z}{l_{0,z}^2} = 3{,}1416^2 \cdot \frac{8079{,}45}{6{,}000^2} = 2215{,}03 \text{ kN}$ EN 1992-1-1 (5.17)

The coefficient which depends on the distribution of first order moment: EN 1992-1-1 5.8.7.3 (1)

$c_{0z} = c_{0,min} + \frac{c_{0,max} - c_{0,min}}{r_{M,max} - r_{M,min}} \cdot (r_{mz} - r_{M,min}) = 12 + \frac{8 - 12}{1 - (-1)} \cdot (0{,}11533 - (-1)) = 9{,}7693$

Coefficient depending on the distribution of curvature due to second order effects:

$c_2 = \pi^2 = 3{,}1416^2 = 9{,}8696$

Coefficient depending on the curvature distribution:

$c_z = c_2 \cdot \frac{N_{Ed}}{N_{bz}} + c_{0z} \cdot \left(1 - \frac{N_{Ed}}{N_{bz}}\right) = 9{,}8696 \cdot \frac{892{,}054}{2215{,}03} + 9{,}7693 \cdot \left(1 - \frac{892{,}054}{2215{,}03}\right) = 9{,}8097 < c_2 = \pi^2 = 3{,}1416^2 = 9{,}8696$

The second order eccentricity:

$e_{2,y} = \frac{\kappa_z \cdot l_{0,z}^2}{c_z} = \frac{0{,}018086 \cdot 6{,}000^2}{9{,}8097} = 0{,}0663735 \text{ m}$ EN 1992-1-1 5.8.8.2 (3)

Position of the section with the highest utilization: $x = 0$ m

$e_{2,x,y} = \cos\left(\frac{\pi \cdot x_{e2}}{2 \cdot l}\right) \cdot e_{2,y} = \cos\left(\frac{3{,}1416 \cdot 0}{2 \cdot 3{,}000}\right) \cdot 0{,}0663735 = 0{,}0663735 \text{ m}$ Cantilever

Minimum eccentricity : EN 1992-1-1 6.1. (4)

$e_{min,y} = \max\left(\frac{h_y}{30}\ ;\ 2\right) = \max\left(\frac{40{,}0}{30}\ ;\ 2\right) = 2 \text{ cm} = 0{,}02 \text{ m}$

$e_{min,z} = \max\left(\frac{h_z}{30}\ ;\ 2\right) = \max\left(\frac{40{,}0}{30}\ ;\ 2\right) = 2 \text{ cm} = 0{,}02 \text{ m}$

The critical eccentricity :

$e_{d,x,y} = e_{e,x,y} + e_{i,x,y} + e_{2,x,y} = 0{,}0596238 + 0{,}015 + 0{,}0663735 = 0{,}140997 \text{ m}$ $e_{d,x,z} = e_{e,x,z} - e_{i,x,z} =$
$= (-0{,}0360287) - 0{,}0075 = -0{,}0435287 \text{ m}$

$|e_{d,x,y}| = 0{,}140997 > e_{min,y} = 0{,}02 \text{ m}$ ✔

$|e_{d,x,z}| = 0{,}0435287 > e_{min,z} = 0{,}02 \text{ m}$ ✔

Column forces in the critical section

Load case: **[G] {±FR1 3} (0,3*Q1+0,3*Q2+0,3*Q3+0,3*Q4+0,3*Q5+0,3*Q6)**

$N_{Ed} = N_{Ed,0} = 892{,}054 \text{ kN}$

$M_{Edy} = N_{Ed} \cdot e_{d,x,z} = 892{,}054 \cdot (-0{,}0435287) = -38{,}8299 \text{ kNm}$

$M_{Edz} = N_{Ed} \cdot e_{d,x,y} = 892{,}054 \cdot 0{,}140997 = 125{,}777 \text{ kNm}$

$M_{Ed} = \sqrt{M_{Edy}^2 + M_{Edz}^2} = \sqrt{(-38{,}8299)^2 + 125{,}777^2} = 131{,}635 \text{ kNm}$

Design value of the resistance at the critical eccentricity:

$N_{Rd(e)} = 1281{,}72 \text{ kN}$

$M_{Rd(e)} = \sqrt{M_{Rd(e)y}{}^2 + M_{Rd(e)z}{}^2} = \sqrt{(-55{,}7917)^2 + 180{,}719^2} = 189{,}135 \text{ kNm}$

Utilization for constant eccentricity:

$$\eta_{(e)m} = \frac{N_{Ed}}{N_{Rd(e)}} = \frac{892{,}054}{1281{,}72} = 0{,}69598 \;\; < 1 \;\; \text{passed}$$

Design value of the resistance at the critical axial force:

$N_{Rd(N)} = N_{Ed} = 892{,}054 \text{ kN}$

$M_{Rd(N)} = \sqrt{M_{Rd(N)y}{}^2 + M_{Rd(N)z}{}^2} = \sqrt{(-55{,}273)^2 + 179{,}039^2} = 187{,}377 \text{ kNm}$

Moment utilization:

$$\eta_{(N)m} = \frac{M_{Ed}}{M_{Rd(N)}} = \frac{131{,}635}{187{,}377} = 0{,}70251 \;\; < 1 \;\; \text{passed}$$