Column reinforcement

Structural member: Beam 8

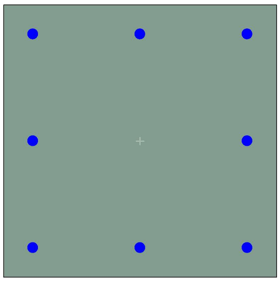
Shear and torsion check

Materials

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

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)

Stirrup

Stirrup zones

	Length $l_{w,}$ $[m]$	Startpoint x_0 $[m]$	Endpoint x_0 $[m]$	Stirrup diameter ϕ_w $[mm]$	Stirrup spacing s_w $[mm]$
Top zone	0,6	2,4	3	10	50
Middle zone	1,8	0,6	2,4	8	175
Bottom zone	0,6	0	0,6	10	50

Number of stirrup legs: n_{wy} = 2 n_{wz} = 2

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 $> s_w$ = 175 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

$0{,}6 \cdot s_{cl,tmax} = 0{,}6 \cdot 32 = 19{,}2 \text{ cm} > s_w = 175 \text{ mm}$ ✔

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

$d_{bw,min} = 6 \text{ mm} < \phi_w = 8 \text{ mm}$ ✔

The concrete cover for stirrups: $c_w = 27$ mm

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

$b_o = b - 2 \cdot c_w = 400 - 2 \cdot 27 = 346 \text{ mm}$

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

$$s_{t,max} = \max\left(\frac{b_o}{2} \; ; \; 175 \; ; \; 8 \cdot d_{bL}\right) = \max\left(\frac{346}{2} \; ; \; 175 \; ; \; 8 \cdot 16\right) = 128 \text{ mm} < s_w = 175 \text{ mm}$$ ✗

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)

$$f_{ctd} = \alpha_{ct} \cdot \frac{f_{ctk,0.05}}{\gamma_c} = 1 \cdot \frac{1{,}79547}{1{,}5} = 1{,}19698 \text{ MPa} = 1196{,}98 \text{ KPa}$$ EN 1992-1-1 3.1.6. (2)P (3.16)

Design yield strength of rebar steel: EN 1992-1-1 3.2.7. (2) Fig. 3.8

$$f_{yd} = \frac{f_{yk}}{\gamma_s} = \frac{500}{1{,}15} = 434{,}783 \approx 435 \text{ MPa} = 435000 \text{ KPa} \qquad f_{ywd} = f_{yd} = 435000 \text{ KPa}$$

Creep factor: $\varphi(\infty, t_0) = 2$

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)**

$N_{Ed} = N_{Ed,0} = 861{,}84 \text{ kN}$

$V_{Edy} = V_{Ed,0y} + V_{Ed,EQ,y} = 2{,}21465 + 20{,}3533 = 22{,}568 \text{ kN}$

$V_{Edz} = V_{Ed,0z} + V_{Ed,EQ,z} = (-0{,}190326) + (-12{,}6074) = -12{,}7978 \text{ kN}$

$T_{Ed} = T_{Ed,0} = 4{,}49048 \text{ kNm}$

Pure shear

Angle of the concrete compression strut: $\Theta = 45{,}00\,° \; (\cot\Theta = 1)$

Shear resistance (y)

The design shear resistance of the member without shear reinforcement: EN 1992-1-1 6.2.2. (1)

$V_{Rd,c,min} = (v_{min} + k_1 \cdot \sigma_{cp}) \cdot b_z \cdot d_y = (0{,}417332 + 0{,}15 \cdot 3{,}33333) \cdot 0{,}4 \cdot 0{,}324589 = 119{,}102 \text{ kN}$ (6.2.b)

$$V_{Rd,c,y} = \left(C_{Rd,c} \cdot k \cdot (100 \cdot \rho_l \cdot f_{ck})^{(1/3)} + k_1 \cdot \sigma_{cp}\right) \cdot b_z \cdot d_y =$$

$$= (0{,}12 \cdot 1{,}785 \cdot (100 \cdot 0{,}0046458 \cdot 25)^{(1/3)} + 0{,}15 \cdot 3{,}33333) \cdot 0{,}4 \cdot 0{,}324589 = 127{,}898 \text{ kN} > V_{Rd,c,min} = 119{,}102 \text{ kN}$$

The design value of shear resistance of the shear reinforcement:

$$V_{Rd,s,y} = \frac{A_{sw}}{s_w} \cdot z_y \cdot f_{ywd} \cdot \cot\Theta = \frac{0{,}000100531}{175} \cdot 0{,}260202 \cdot 435 \cdot \cot 45{,}00° = 65{,}0222 \text{ kN}$$ EN 1992-1-1 (6.8.)

The design value of shear resistance:

$$V_{Rd,max,y} = \frac{\alpha_{cw} \cdot b_z \cdot z_y \cdot v_1 \cdot f_{cd}}{\cot\Theta + \tan\Theta} = \frac{1{,}25 \cdot 0{,}4 \cdot 0{,}260202 \cdot 0{,}54 \cdot 16666{,}7}{\cot 45{,}00° + \tan 45{,}00°} = 585{,}454 \text{ kN}$$ EN 1992-1-1 (6.9.)

The shear resistance of the cross-section:

$$V_{Rd,y} = \min(\max(V_{Rd,c,y} ; V_{Rd,s,y}) ; V_{Rd,max,y}) = \min(\max(127{,}898 ; 65{,}0222) ; 585{,}454) = 127{,}898 \text{ kN}$$

Shear resistance (z)

$$V_{Rd,c,min} = (v_{min} + k_1 \cdot \sigma_{cp}) \cdot b_y \cdot d_z = (0{,}417332 + 0{,}15 \cdot 3{,}33333) \cdot 0{,}4 \cdot 0{,}324589 = 119{,}102 \text{ kN}$$

$$V_{Rd,c,z} = \left(C_{Rd,c} \cdot k \cdot (100 \cdot \rho_l \cdot f_{ck})^{(1/3)} + k_1 \cdot \sigma_{cp}\right) \cdot b_y \cdot d_z =$$

$$= (0{,}12 \cdot 1{,}785 \cdot (100 \cdot 0{,}0046458 \cdot 25)^{(1/3)} + 0{,}15 \cdot 3{,}33333) \cdot 0{,}4 \cdot 0{,}324589 = 127{,}898 \text{ kN} > V_{Rd,c,min} = 119{,}102 \text{ kN}$$

$$V_{Rd,s,z} = \frac{A_{swz}}{s_w} \cdot z_z \cdot f_{ywd} \cdot \cot\Theta = \frac{0{,}000100531}{175} \cdot 0{,}260202 \cdot 435 \cdot \cot 45{,}00° = 65{,}0222 \text{ kN}$$

$$V_{Rd,max,z} = \frac{\alpha_{cw} \cdot b_y \cdot z_z \cdot v_1 \cdot f_{cd}}{\cot\Theta + \tan\Theta} = \frac{1{,}25 \cdot 0{,}4 \cdot 0{,}260202 \cdot 0{,}54 \cdot 16666{,}7}{\cot 45{,}00° + \tan 45{,}00°} = 585{,}454 \text{ kN}$$

$$V_{Rd,z} = \min(\max(V_{Rd,c,z} ; V_{Rd,s,z}) ; V_{Rd,max,z}) = \min(\max(127{,}898 ; 65{,}0222) ; 585{,}454) = 127{,}898 \text{ kN}$$

Check

Shear utilization in y and z direction:

$$\eta_{V,y} = \frac{|V_{Edy}|}{V_{Rd,y}} = \frac{|22{,}568|}{127{,}898} = 0{,}17645 < 1 \text{ passed} \qquad \eta_{V,z} = \frac{|V_{Edz}|}{V_{Rd,z}} = \frac{|(-12{,}7978)|}{127{,}898} = 0{,}10006 < 1 \text{ passed}$$

Overall shear utilization without torsion:

$$\eta_V = \frac{|V_{Edy}|}{V_{Rd,y}} + \frac{|V_{Edz}|}{V_{Rd,z}} = \frac{|22{,}568|}{127{,}898} + \frac{|(-12{,}7978)|}{127{,}898} = 0{,}27652 < 1 \text{ passed}$$

Shear with torsion

Torsion resistance

The torsional cracking moment:

$$T_{Rd,c} = f_{ctd} \cdot t_{efi} \cdot 2 \cdot A_k = 1196{,}98 \cdot 0{,}1 \cdot 2 \cdot 0{,}09 = 21{,}5457 \text{ kNm}$$ EN 1992-1-1 6.3.2. (5)

Utilization of the concrete for shear and torsion (without shear and torsion reinforcement):

$$\eta_{VyVzTRdc} = \frac{|V_{Edy}|}{V_{Rd,c,y}} + \frac{|V_{Edz}|}{V_{Rd,c,z}} + \frac{|T_{Ed}|}{T_{Rd,c}} = \frac{|22{,}568|}{127{,}898} + \frac{|(-12{,}7978)|}{127{,}898} + \frac{|4{,}49048|}{21{,}5457} = 0{,}48493 < 1$$

Torsion can be ignored when checking stirrups.
All stirrups can be taken into account for shear resistance.

Maximum torsion resistance

The design torsional resistance moment based on the capacity of concrete struts:

$T_{Rd,max} = 2 \cdot v \cdot \alpha_{cw} \cdot f_{cd} \cdot A_k \cdot t_{efi} \cdot \sin\Theta \cdot \cos\Theta = 2 \cdot 0{,}54 \cdot 1{,}25 \cdot 16666{,}7 \cdot 0{,}09 \cdot 0{,}1 \cdot \sin 45{,}00° \cdot \cos 45{,}00° = 101{,}25$ kNm EN 1992-1-1 (6.30)

Check

Overall utilization with shear and torsion interaction:

Torsion is negligible

$\eta_{VyVzT} = \eta_V = 0{,}27652 < 1$ passed

Utilization of concrete compression struts (shear and torsion):

$$\eta_{VyVzTRdmax} = \frac{|V_{Edy}|}{V_{Rd,max,y}} + \frac{|V_{Edz}|}{V_{Rd,max,z}} + \frac{|T_{Ed}|}{T_{Rd,max}} = \frac{|22{,}568|}{585{,}454} + \frac{|(-12{,}7978)|}{585{,}454} + \frac{|4{,}49048|}{101{,}25} = 0{,}10476 < 1 \text{ passed}$$

Additional longitudinal reinforcement for torsion

Load case: **[1,35*0,85*G] {1,5*Q6} (1,5*0,7*Q3+1,5*0,7*Q4+1,5*0,7*Q5+1,5*0,6*Wind)**

$T_{Ed} = 22{,}46$ kNm

The required cross-sectional area of the longitudinal reinforcement for torsion:

$$\Sigma A_{sl} = \frac{T_{Ed}}{2 \cdot A_k} \cdot \cot\Theta \cdot \frac{u_k}{f_{yd}} = \frac{22{,}46}{2 \cdot 0{,}09} \cdot \cot 45{,}00° \cdot \frac{1{,}2}{435000} = 0{,}00034421 \text{ m}^2 = 3{,}44 \text{ cm}^2$$ EN 1992-1-1 (6.28)