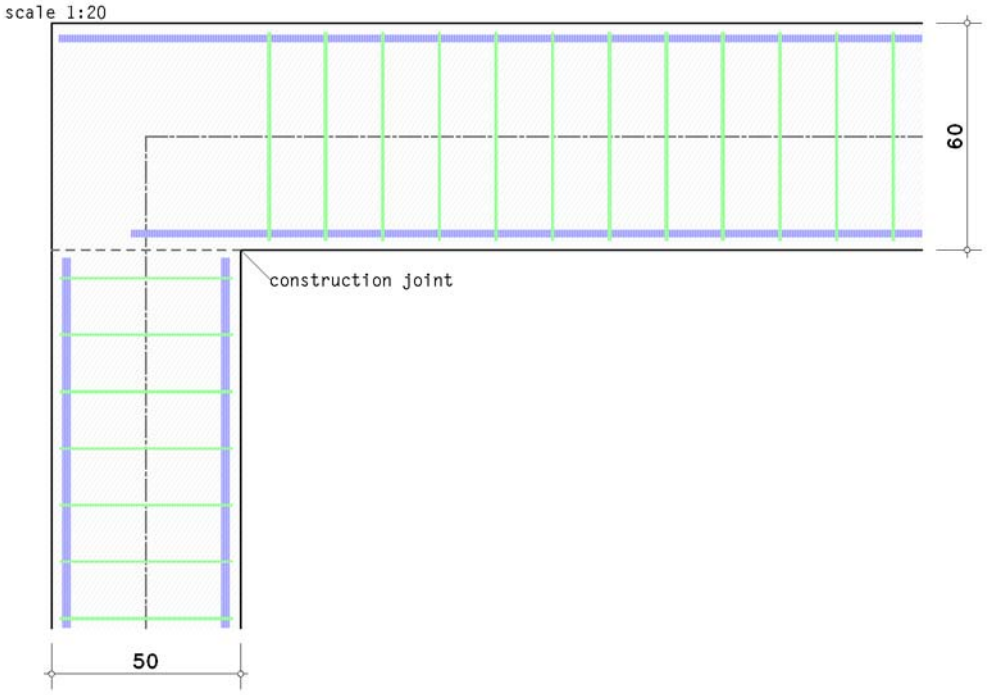
dimensioning a frame corner EC 2 (1.11), NA: Deutschland

1. input protocol



system
beam: height h_b = 60.0 cm, axis distances (design calculation) $d_{1,bo}$ = 5.0 cm, $d_{1,bu}$ = 4.0 cm
column: height h_c = 50.0 cm, axis distances (design calculation) $d_{1,cl}$ = 5.0 cm, $d_{1,cr}$ = 4.0 cm
opening angle α = 90.00°, width beam/column $b_b = b_c$ = 40.0 cm
material properties
concrete acc. to EC 2, 3.1.7(1): C30/37, reinforcement acc. to EC 2, 3.2.7(2a): B500A
material safety factors
design situation: basic combination
design resistance: concrete γ_c = 1.50, reinforcement γ_s = 1.15
parameters
dimensioning a frame corner with a positive moment
req. reinforcement at the cut:
beam: $A_{s,bo}$ = 0.00 cm², $A_{s,bu}$ = 10.00 cm², $a_{sb,b}$ = 0.00 cm²($F_{c,b}$ = 0.0 kN, z_b = 0.0 cm)
column: $A_{s,cl}$ = 0.00 cm², $A_{s,cr}$ = 12.50 cm², $a_{sb,c}$ = 0.00 cm²/m($F_{c,c}$ = 0.0 kN, z_c = 0.0 cm)
calculation of the required anchorage lengths: calculate bonding conditions
diameter of mandrel unabhängig vom concreterandabstand
beam-/column reinforcement from an external structural analysis
beam: above 2Ø20, bottom 4Ø20, stirrup Ø8/15.0 cm
column: left 2Ø20, right 4Ø20, stirrup Ø8/15.0 cm

1.1. durability and concrete cover

öffnendes Moment (Zug internal):
beam: minimum strength class, concrete cover
due to reinforcement corrosion XC1 ⇒ C16/20, c_{nom} = 20 mm, $c_{nom,b}$ = 18 mm, $c_{nom,l}$ = 12 mm
⇒ c_{nom} = 20 mm ≤ c_v = 20 mm ok
minimum concrete quality C16/20 with f_{ck} = 16.0 N/mm² < exst f_{ck} = 30.0 N/mm² ok
column: minimum strength class, concrete cover
due to reinforcement corrosion XC1 ⇒ C16/20, c_{nom} = 20 mm, $c_{nom,b}$ = 18 mm, $c_{nom,l}$ = 12 mm
⇒ c_{nom} = 20 mm ≤ c_v = 20 mm ok
minimum concrete quality C16/20 with f_{ck} = 16.0 N/mm² < exst f_{ck} = 30.0 N/mm² ok

2. note

general reinforcement rules are not taken into account.

3. design calculation

3.1. results table

required reinforcement

lc	$A_{s,bu}$ cm²	$A_{s,cr}$ cm²
	10.00	12.50

$A_{s,bu}$: req. reinforcement in beam; $A_{s,ct}$: req. reinforcement in column

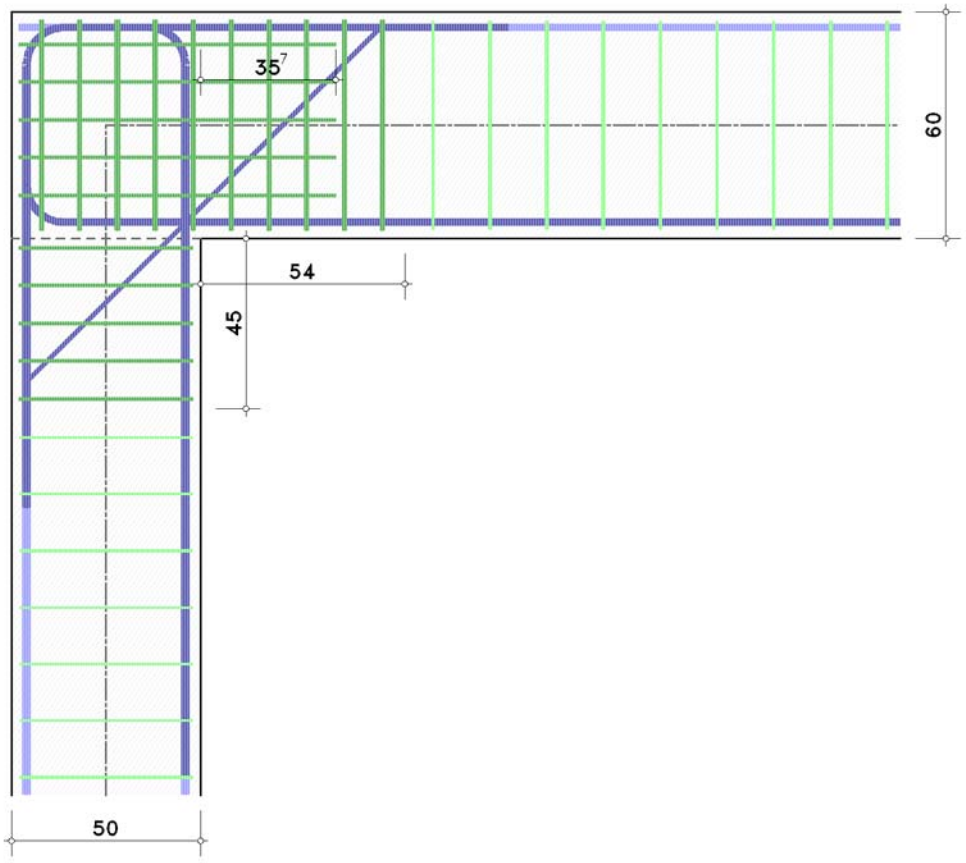
4. final result

transverse reinforcement: req $A_{s,S} = 0.5 \cdot \max(A_{s,cr}, A_{s,bu}) = 6.25$ cm²
compression brackets horiz.: req $a_{s,sh} = F_u / (f_{yd} \cdot (h_b + \Delta h_c)) = 0.00$ cm²/m, $\Delta h_c = 0.9 \cdot h_c = 45.0$ cm
compression brackets vert.: req $a_{s,sv} = F_u / (f_{yd} \cdot (h_c + \Delta h_b)) = 0.00$ cm²/m, $\Delta h_b = 0.9 \cdot h_b = 54.0$ cm

maximum reinforcement: $A_{s,bu} = 10.00$ cm², $A_{s,cr} = 12.50$ cm², $A_{s,S} = 6.25$ cm²

5. selected reinforcement

scale 1:20



anchorage length of transverse reinforcement
bond area good
design value of bond strength for $f_{ck} = 30.0$ N/mm², $\varnothing_s = 12.0$ mm: $f_{bd} = 3.04$ N/mm²
basic value of anchorage length for $f_{yd} = 434.8$ N/mm²: $l_{b,rqd} = 0.25 \cdot \varnothing_s \cdot f_{yd} / f_{bd} = 42.89$ cm
minimum anchorage length for $\alpha_i = 1.00$: $l_{b,min} = \min(0.3 \cdot \alpha_i \cdot l_{b,rqd}, 10 \cdot \varnothing_s, 20\text{ cm}) = 20.00$ cm
design value of anchorage length for $\alpha_i = 1.00$, $A_{s,req} = 6.25$ cm², $A_{s,exst} = 6.79$ cm²:
$l_b = A_{s,req} / A_{s,exst} \cdot \alpha_i \cdot l_{b,rqd} = 39.50$ cm
bond area good
design value of bond strength for $f_{ck} = 30.0$ N/mm², $\varnothing_s = 12.0$ mm: $f_{bd} = 3.04$ N/mm²
basic value of anchorage length for $f_{yd} = 434.8$ N/mm²: $l_{b,rqd} = 0.25 \cdot \varnothing_s \cdot f_{yd} / f_{bd} = 42.89$ cm
minimum anchorage length for $\alpha_i = 1.00$: $l_{b,min} = \min(0.3 \cdot \alpha_i \cdot l_{b,rqd}, 10 \cdot \varnothing_s, 20\text{ cm}) = 20.00$ cm
design value of anchorage length for $\alpha_i = 1.00$, $A_{s,req} = 6.25$ cm², $A_{s,exst} = 6.79$ cm²:
$l_b = A_{s,req} / A_{s,exst} \cdot \alpha_i \cdot l_{b,rqd} = 39.50$ cm
lap length of tensile anchoring reinforcement of column in tension area
reduction factor for ρ_1 = req $A_{s,cr}$ / exst $A_{s,cr} = 0.995$, $\varnothing_{s,cr} = 20$ mm:
$\alpha_i = \alpha_1 \cdot \alpha_6 = 2.00$, $\alpha_1 = 1$, $\alpha_6 = 2.00$
bond area good
design value of bond strength for $f_{ck} = 30.0$ N/mm², $\varnothing_s = 20.0$ mm: $f_{bd} = 3.04$ N/mm²
basic value of anchorage length for $f_{yd} = 434.8$ N/mm²: $l_{b,rqd} = 0.25 \cdot \varnothing_s \cdot f_{yd} / f_{bd} = 71.48$ cm
minimum anchorage length for $\alpha_i = 2.00$: $l_{b,min} = \min(0.3 \cdot \alpha_i \cdot l_{b,rqd}, 15 \cdot \varnothing_s, 20\text{ cm}) = 42.89$ cm
design value of anchorage length for $\alpha_i = 2.00$, $A_{s,req} = 12.50$ cm², $A_{s,exst} = 12.57$ cm²:
$l_b = A_{s,req} / A_{s,exst} \cdot \alpha_i \cdot l_{b,rqd} = 142.20$ cm

lap length of tensile anchoring reinforcement of column in compression area
bond area good
design value of bond strength for f_{ck} = 30.0 N/mm², $Ø_s$ = 20.0 mm: f_{bd} = 3.04 N/mm²
basic value of anchorage length for f_{yd} = 434.8 N/mm²: $l_{b,rqd} = 0.25 \cdot Ø_s \cdot f_{yd}/f_{bd}$ = 71.48 cm
minimum anchorage length for α_i = 1.00: $l_{b,min} = \min(0.3 \cdot \alpha_i \cdot l_{b,rqd}, 15 \cdot Ø_s, 20\text{ cm})$ = 30.00 cm
design value of anchorage length for α_i = 1.00, $A_{s,req}$ = 12.50 cm², $A_{s,exst}$ = 12.57 cm²:
$l_b = A_{s,req}/A_{s,exst} \cdot \alpha_i \cdot l_{b,rqd}$ = 71.10 cm
diameter of mandrel of tensile anchoring reinforcement of column
diameter of mandrel of bars: $D = 10 \cdot Ø_s$ = 20.0 cm for min c = 400.0 mm > 100 mm and > $7 \cdot Ø_s$ = 140 mm
max. number of bars in the area of tensile anchoring reinforcement of column
max $n_c = b_{net}/s_c$ = 6 for $b_{net} = b_c - 2 \cdot (c_v + \Phi_{c,bü} + \Phi_c/2)$ = 32.0 cm, s_c = min $s_c + \Phi_c$ = 6.0 cm
lap length of tensile anchoring reinforcement of beam in compression area
bond area for h = 60.0 cm, h_z = 4.20 cm: moderate
design value of bond strength for f_{ck} = 30.0 N/mm², $Ø_s$ = 20.0 mm: f_{bd} = 2.13 N/mm²
basic value of anchorage length for f_{yd} = 434.8 N/mm²: $l_{b,rqd} = 0.25 \cdot Ø_s \cdot f_{yd}/f_{bd}$ = 102.11 cm
minimum anchorage length for α_i = 1.00: $l_{b,min} = \min(0.3 \cdot \alpha_i \cdot l_{b,rqd}, 15 \cdot Ø_s, 20\text{ cm})$ = 30.63 cm
design value of anchorage length for α_i = 1.00, $A_{s,req}$ = 10.00 cm², $A_{s,exst}$ = 12.57 cm²:
$l_b = A_{s,req}/A_{s,exst} \cdot \alpha_i \cdot l_{b,rqd}$ = 81.26 cm
diameter of mandrel of tensile anchoring reinforcement of beam
diameter of mandrel of bars: $D = 10 \cdot Ø_s$ = 20.0 cm for min c = 400.0 mm > 100 mm and > $7 \cdot Ø_s$ = 140 mm
max. number of bars in the area of tensile anchoring reinforcement of beam
max $n_b = b_{net}/s_b$ = 6 for $b_{net} = b_b - 2 \cdot (c_v + \Phi_{b,bü} + \Phi_b/2)$ = 31.6 cm, s_b = min $s_b + \Phi_b$ = 6.0 cm
anchorage length of horizontaln tensile splitting reinforcement
bond area for h = 60.0 cm, h_z = 7.20 cm: moderate
design value of bond strength for f_{ck} = 30.0 N/mm², $Ø_s$ = 10.0 mm: f_{bd} = 2.13 N/mm²
basic value of anchorage length for f_{yd} = 434.8 N/mm²: $l_{b,rqd} = 0.25 \cdot Ø_s \cdot f_{yd}/f_{bd}$ = 51.06 cm
minimum anchorage length for α_i = 1.00: $l_{b,min} = \min(0.3 \cdot \alpha_i \cdot l_{b,rqd}, 10 \cdot Ø_s)$ = 15.32 cm
design value of anchorage length for α_i = 1.00: $l_b = \alpha_i \cdot l_{b,rqd}$ = 51.06 cm
diameter of mandrel of horizontaln tensile splitting reinforcement
diameter of mandrel for stirrup/U-bents: $D = 4 \cdot Ø_s$ = 4.0 cm for $Ø_s$ = 10 mm < 20 mm
diameter of mandrel of vertical tensile splitting reinforcement
diameter of mandrel for stirrup/U-bents: $D = 4 \cdot Ø_s$ = 4.8 cm for $Ø_s$ = 12 mm < 20 mm
diameter of mandrel of tensile reinforcement of beam
diameter of mandrel of bars: $D = 10 \cdot Ø_s$ = 20.0 cm for min c = 400.0 mm > 100 mm and > $7 \cdot Ø_s$ = 140 mm
lap length of tensile reinforcement of beam in compression area
bond area for h = 60.0 cm, h_z = 3.20 cm: moderate
design value of bond strength for f_{ck} = 30.0 N/mm², $Ø_s$ = 20.0 mm: f_{bd} = 2.13 N/mm²
basic value of anchorage length for f_{yd} = 434.8 N/mm²: $l_{b,rqd} = 0.25 \cdot Ø_s \cdot f_{yd}/f_{bd}$ = 102.11 cm
minimum anchorage length for α_i = 1.00: $l_{b,min} = \min(0.3 \cdot \alpha_i \cdot l_{b,rqd}, 15 \cdot Ø_s, 20\text{ cm})$ = 30.63 cm
design value of anchorage length for α_i = 1.00, $A_{s,req}$ = 10.00 cm², $A_{s,exst}$ = 12.57 cm²:
$l_b = A_{s,req}/A_{s,exst} \cdot \alpha_i \cdot l_{b,rqd}$ = 81.26 cm

verification of reinforcement

concrete cover c_v = 2.0 cm = c_{nom} = 2.00 cm ok
beam reinforcement:
above bar reinforcement, 2Ø20, exst $A_{s,bo}$ = 6.28 cm², req $A_{s,bo}$ = 0
bar distance s_{bo} = 31.6 cm > min s_{bo} = 4.0 cm ok
bottom bar reinforcement, 4Ø20, exst $A_{s,bu}$ = 12.57 cm² > req $A_{s,bu}$ = 10.00 cm² ok
bar distance s_{bu} = 10.5 cm > min s_{bu} = 4.0 cm ok
transverse stirrup, Ø8/15.0 cm (2-shear), exst $a_{s,bb}$ = 6.70 cm²/m, req $a_{s,bb}$ = 0
column reinforcement:
left bar reinforcement, 2Ø20, exst $A_{s,cl}$ = 6.28 cm², req $A_{s,cl}$ = 0
bar distance s_{cl} = 32.0 cm > min s_{cl} = 4.0 cm ok
right bar reinforcement, 4Ø20, exst $A_{s,cr}$ = 12.57 cm² > req $A_{s,cr}$ = 12.50 cm² ok
bar distance s_{cr} = 10.7 cm > min s_{cr} = 4.0 cm ok
transverse stirrup, Ø8/15.0 cm (2-shear), exst $a_{s,bc}$ = 6.70 cm²/m, req $a_{s,bc}$ = 0
tensile anchoring reinforcement of beam (bar reinforcement, 4Ø20, exst $A_{s,bu}$ = 12.57 cm², s. beam bottom):
lap length compression $l_{b,bu,c}$ = 81.3 cm = req $l_{b,bu,c}$ = 81.3 cm ok
diameter of mandrel D_{bu} = 20.0 cm = req D_{bu} = 20.0 cm ok
bar number n_b = max(n_{bo}, n_{bu}) = 4 < perm n_b = 6 ok
tensile anchoring reinforcement of column (bar reinforcement, 4Ø20, exst $A_{s,cr}$ = 12.57 cm², s. column right):
lap length Zug $l_{b,cr,t}$ = 142.2 cm = req $l_{b,cr,t}$ = 142.2 cm ok
compression $l_{b,cr,c}$ = 71.1 cm = req $l_{b,cr,c}$ = 71.1 cm ok
diameter of mandrel D_{cr} = 20.0 cm = req D_{cr} = 20.0 cm ok
U-bent length right $l_{cr} = h_b - c_v - \Phi_{bü} + l_{b,cr}$ = 199.0 cm (overlapping from the column cut)
left $l_{cl} = h_b - c_v - \Phi_{bü} + l_{b,cl}$ = 127.9 cm (overlapping from the column cut)
bar number n_c = max(n_{cl}, n_{cr}) = 4 < perm n_c = 6 ok
transverse reinforcement:
bar reinforcement, 6Ø12, exst $A_{s,S}$ = 6.79 cm² > req $A_{s,S}$ = 6.25 cm² ok
bar distance ss = 6.1 cm > min ss = 3.2 cm ok
anchorage length beam $l_{b,S,b}$ = 79.0 cm = req $l_{b,S,b}$ = 79.0 cm ok
column $l_{b,S,c}$ = 65.4 cm = req $l_{b,S,c}$ = 65.4 cm ok
tensile splitting reinforcement:

horiz. U-bents/stirrup, Ø10/10.0 cm (2-shear), exst $a_{s,sh}$ = 15.71 cm²/m, req $a_{s,sh}$ = 0
anchorage length $l_{b,sh}$ = 35.7 cm < req $l_{b,sh}$ = 51.1 cm not ok !!
diameter of mandrel min D_{sh} = 4.0 cm
U-bent length $l_{sh} = h_c - c_v + l_{b,sh}$ = 83.7 cm (anchoring from the beam cut)
vertical stirrup, Ø12/10.0 cm (2-shear), exst $a_{s,sv}$ = 22.62 cm²/m, req $a_{s,sv}$ = 0
diameter of mandrel min D_{sv} = 4.8 cm

design resistance not guaranteed !!

s. selected reinforcement

6. regulations

EN 1990, Eurocode 0: Grundlagen der Tragwerksplanung;
Deutsche Fassung EN 1990:2002 + A1:2005 + A1:2005/AC:2010, Ausgabe Dezember 2010
EN 1990/NA, Nationaler Anhang zur EN 1990, Ausgabe Dezember 2010

EN 1992-1-1, Eurocode 2: Bemessung und Konstruktion von Stahlbeton- und Spannbetonbauteilen -
Teil 1-1: Allgemeine Bemessungsregeln und Regeln for den Hochbau;
Deutsche Fassung EN 1992-1-1:2004 + AC:2010, Ausgabe Januar 2011
EN 1992-1-1/NA, Nationaler Anhang zur EN 1992-1-1, Ausgabe April 2013