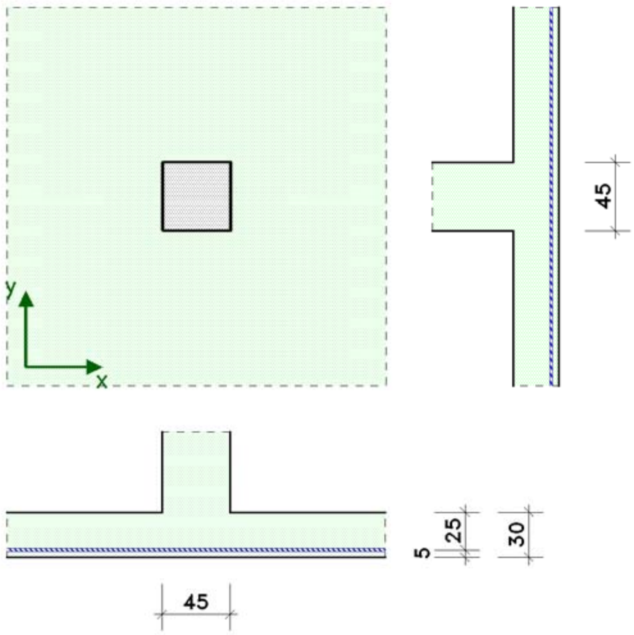
POS. 56: FOUNDATION SLAB

Punching shear calculation column on foundation slab

Acc. to DIN EN 1992-1-1 (EC 2, 1.11) with National Annex Germany
(4H-STANZ version: 8/2012-1a)

scale 1:50



spans
L_x = 4.00 m
L_y = 4.00 m

anchored tension reinforcement
$a_{s,zug,x}$ = 30.00 cm² /m
$a_{s,zug,y}$ = 33.50 cm² /m

concrete strength class **C35/45**
steel class **BSt 500 S(A)**

1. Load

design values of punching shear load in centroid of load distribution

LK	notation	design situat.	V_{Ed} kN	$M_{Ed,x}$ kNm	$M_{Ed,y}$ kNm	$\sigma_{Ed,gd,m}$ kN/m²
1	new load comb.	permanent	1400.00	200.00	50.00	0.00

V_{Ed} - shear force $M_{Ed,x}/M_{Ed,y}$ - moments $\sigma_{Ed,gd,m}$ - mean ground pressure

2. Material safety factors

design situat.	γ_c	γ_s
permanent	1.50	1.15

3. Action within the basic control perimeter

$v_{Ed,crit} = \beta \cdot (V_{Ed} - \Delta V_{Ed})/(u_1 \cdot d)$
$\Delta V_{Ed} = A_{crit} \cdot \sigma_{Ed,gd,m}$
$\beta = 1 + \text{sqrt}(\ (k_x \cdot M_{Ed,x}/V_{Ed} \cdot u_1/W_{1,x})^2 + (k_y \cdot M_{Ed,y}/V_{Ed} \cdot u_1/W_{1,y})^2\ ) \geq 1.10$
$W_1 = \int |e|\ dl$ mit dl:differential of perimeter
e :distance of dl to axis of M_{Ed}

coefficient for the calculation of shear stresses from moment action
(acc. to [1], table 6.1)
$c_1 = c_2 = 0.45 \Rightarrow k_x = k_y = 0.6$

distance and length of the basic control perimeter
$a_1 = 1 \cdot d = 25$ cm $\Rightarrow u_1 = 3.37$ m

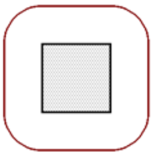
area under basic control perimeter
A_{crit} = 0.85 m²

moment of resistance alongside the basic control perimeter
- at moment action about the x-axis $W_{1,x}$ = 1.13 m²
- at moment action about the y-axis $W_{1,y}$ = 1.13 m²

LK	V_{Ed}	ΔV_{Ed}	$M_{Ed,x}$	$M_{Ed,y}$	β	$v_{Ed,crit}$
-	kN	kN	kNm	kNm	-	N/mm²
1	1400.00	0.00	200.00	50.00	1.26	**2.098**

W_1 - moment of resistance alongside the basic control perimeter ΔV_{Ed} - reultant of ground pressure
β - load increase factor from eccentric load $v_{Ed,crit}$ - decisive shear stress within the basic control perimeter

4. Punching shear resistance within the basic control perimeter



$v_{Rd,c} = C_{Rd,c} \cdot k \cdot (100 \cdot \rho_{l,zug} \cdot f_{ck})^{1/3} \cdot 2 \cdot d/a \geq v_{min} \cdot 2 \cdot d/a$ [N/mm²]
$C_{Rd,c} = 0.18/\gamma_c$
$k = 1 + \text{sqrt}(200/d) \leq 2.0$ with d [mm]
$\rho_{l,zug,max} = \min(0.02,\ 0.5 f_{cd}/f_{yd})$
$\rho_{l,zug} = \text{sqrt}(\rho_{lx,zug} \cdot \rho_{ly,zug}) \leq \rho_{l,zug,max}$
$v_{min} = 0.0525/\gamma_c \cdot k^{3/2} \cdot f_{ck}^{1/2}$ for $d \leq 600$ mm

scale factor
$k = 1 + \text{sqrt}(200/250) = 1.89 < 2$

longitudinal reinf. ratio of the anchored tension reinf.
mean of the tension reinforcement to the distance 3d from the column
$\rho_{lx,zug} = 30/25 \cdot 10^{-2} = 0.012$
$\rho_{ly,zug} = 33.5/25 \cdot 10^{-2} = 0.0134$
$\rho_{l,zug} = \text{sqrt}(0.012 \cdot 0.0134) = 0.01268$

punching shear resistance without shear reinforcement
$C_{Rd,c} = 0.18/1.5 = 0.12$
$\rho_{l,zug,max} = \min(0.02,\ 0.5 \cdot 19.83/434.78) = 0.02 > 0.0127$
$v_{min} \cdot 2 \cdot d/a = 0.0525/1.5 \cdot 1.89^{3/2} \cdot 35^{0.5} \cdot 2 \cdot 25/25 = 1.08$ N/mm²
$v_{Rd,c} = 0.12 \cdot 1.89 \cdot (100 \cdot 0.01268 \cdot 35)^{1/3} \cdot 2 \cdot 25/25 = 1.61$ N/mm² > 1.08 N/mm²

2.098 N/mm² > 1.61 N/mm² ⇒ shear reinforcement required

maximal load-bearing resistance
$v_{Rd,max} = 1.4 \cdot v_{Rd,c}$

$v_{Rd,max} = 1.4 \cdot 1.61 = 2.254$ N/mm²

2.098 N/mm² < 2.254 N/mm² ⇒ $v_{Ed,crit}$ enabled to resist with shear reinforcement

5. Design calculation

minimum reinforcement of the first two reinforcement rows
$A_{sw,1+2} = \beta \cdot (V_{Ed} - \Delta V_{Ed})/f_{ywd,ef}$
$f_{ywd,ef} = 250 + 0.25 \cdot d \leq f_{ywd}$

$f_{ywd,ef} = 250 + 0.25 \cdot 250 = 312.5$ N/mm²
$f_{ywd} = 500/1.15 = 434.8$ N/mm² > 312.5 N/mm²
$A_{sw,1+2} = 1.26 \cdot (1400 - 0)/31.25 = 56.58$ cm²

5.1. Stirrup reinforcement rows

$A_{sw,min} = 0.50 \cdot A_{sw,1+2}$ for 1. and 2. row
$A_{sw,min} = 0.33 \cdot A_{sw,1+2}$ from 3. row onwards
$A_{sw,min} = 0.08/1.5 \cdot f_{ck}^{0.5}/f_{yk} \cdot s_r \cdot u$

bar diameter
max $Ø_{sw} \leq 0.05 \cdot 250 \approx 13$ mm ⇒ **selected Ø 10**
information on erection of 10er stirrups: both reinforcement layers have to be covered

Nr	$A_{sw,min}$	s_r	l_w	u	$A_{sw,min}$	min n	selected	$\bar{s}_t$	$A_{sw,exis}$
	cm²	cm	cm	m	cm²	-	leg	cm	cm²
1	28.29	7.5	7.5	2.27	1.07	7	**38 Ø 10**	6.0	29.85
2	28.29	12.5	20.0	3.06	2.41	9	**38 Ø 10**	8.0	29.85
3	18.67	18.8	38.8	4.23	5.01	9	**24 Ø 10**	17.6	18.85
4	18.67	18.8	57.5	5.41	6.40	11	**24 Ø 10**	22.6	18.85
5	18.67	18.8	76.3	6.59	7.80	14	**24 Ø 10**	27.5	18.85
6	18.67	18.8	95.0	7.77	9.19	16	**24 Ø 10**	32.4	18.85
7	18.67	18.8	113.8	8.95	10.59	18	**24 Ø 10**	37.3	18.85

permitted spacing of link legs:
$s_t \leq 37.5$ cm in der 1. and 2. Reihe
$s_t \leq 50.0$ cm in der 3., 4., 5., 6. and 7. Reihe

information on the positional tolerance:
acc. to [2] radial deflection up to ±0.2d (here ±5.0cm) concerning theoretical section allowed.
in contrast for foundations and foundation slabs the first row should lie exactly at 0.3d liegen.

s_r - distance to preceding row in radial direction l_w - distance to column edge u - length of effective control perimeter
$A_{sw,min}$ - minimum shear reinforcement of total row $\bar{s}_t$ - mean spacing of link legs in section

5.2. Verification of outer control perimeter

shear resistance at a distance of 1.5d from the last reinforcement row

$v_{Rd,c} = C_{Rd,c} \cdot k \cdot (100 \cdot \rho_{l,zug} \cdot f_{ck})^{1/3} \cdot 2 \cdot d/a \geq v_{min} \cdot 2 \cdot d/a$ [N/mm²]

$C_{Rd,c} = 0.15/\gamma_c$

perimeter of outer control perimeter

$l_{w,out} = 113.8 + 1.5 \cdot 25 = 151.3$ cm $\Rightarrow u_{out} = 11.3$ m

reduction value from ground pressure in control perimeter

$A_{out} = 10.112$ m²

$\Delta V_{Ed} = 10.112 \cdot 0 = 0$ kN

decisive shear stress

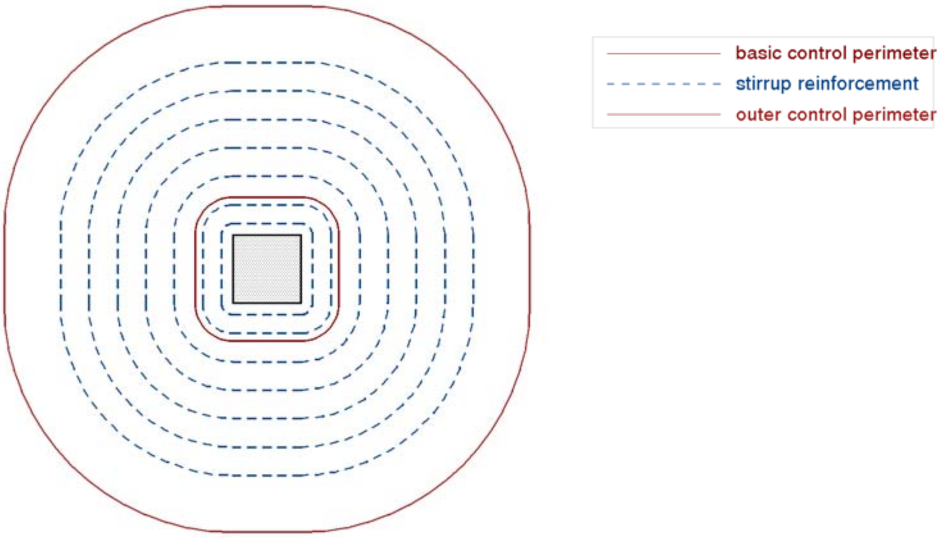
$v_{Ed,out} = 1.26 \cdot (1.4-0)/(11.3 \cdot 0.25) = 0.626$ N/mm²

shear resistance

$C_{Rd,c} = 0.15/1.5 = 0.1$

$v_{Rd,c} = 0.1 \cdot 1.89 \cdot (100 \cdot 0.01268 \cdot 35)^{1/3} = 0.671$ N/mm² > 0.54 N/mm²

0.626 N/mm² < 0.671 N/mm² ⇒ Verification done



6. Minimum longitudinal reinforcement to ensure shear resistance

acc. to [1] table tab. NA.6.1.1

reduction value from ground pressure below load distribution

$A_{Load} = 0.203$ m²

$\Delta V_{Ed} = 0.203 \cdot 0 = 0$ kN

tension face	direction	η	$m_{Ed,min}$ kNm/m	$a_{su,min}$ cm²/m	$a_{so,min}$ cm²/m	distribution width m
top	x	0.125	175.00	17.00	----	1.20
	y	0.125	175.00	17.00	----	1.20

η - moment coefficient $m_{Ed,min} = \eta \cdot V_{Ed}$ - minimum design moment

[1] DIN EN 1992-1-1: Eurocode 2: Bemessung und Konstruktion von Stahlbeton- und Spannbetontragwerken, Teil 1-1, Januar 2011
[2] DAfStb Heft 525: Erläuterungen zu DIN 1045-1, 2. überarb. Aufl., Beuth, 2010