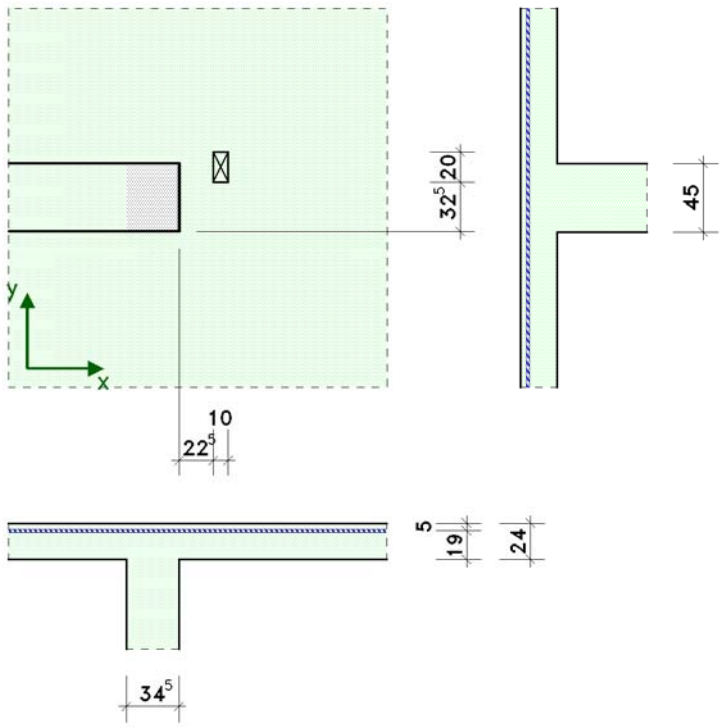
POS. 46: END OF WALL AND OPENING

Punching shear calculation for end of wall below floor 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



anchored tension reinforcement
$a_{s,zug,x}$ = 22.00 cm²/m
$a_{s,zug,y}$ = 22.00 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
1	full load	permanent	350.00	0.00	0.00

V_{Ed} - shear force $M_{Ed,x}/M_{Ed,y}$ - moments

2. Material safety factors

design situat.	γ_c	γ_s
permanent	1.50	1.15

3. Action within the basic control perimeter

$v_{Ed,crit} = \beta \cdot V_{Ed}/(u_1 \cdot d)$

distance and length of the basic control perimeter
$a_1 = 2 \cdot d = 38$ cm $\Rightarrow u_1 = 2.33$ m

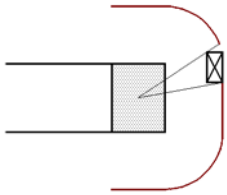
load increase factor acc. to figure 6.21DE
end of wall $\Rightarrow \beta = 1.35$

LK -	V_{Ed} kN	$v_{Ed,crit}$ N/mm²
1	350.00	**1.066**

$v_{Ed,crit}$ - decisive shear stress within the basic control perimeter

4. Punching shear resistance within the basic control perimeter

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



scale factor

$k = 1 + \sqrt{200/190} = 2.03 > 2 \Rightarrow k = 2$

longitudinal reinf. ratio of the anchored tension reinf.

mean of the tension reinforcement to the distance 3d from the column

$\rho_{lx,zug} = 22/19 \cdot 10^{-2} = 0.01158$
$\rho_{ly,zug} = 22/19 \cdot 10^{-2} = 0.01158$
$\rho_{l,zug} = \sqrt{0.01158 \cdot 0.01158} = 0.01158$

punching shear resistance without shear reinforcement

$C_{Rd,c} = 0.18/1.5 = 0.12$
$\rho_{l,zug,max} = \min(0.02,\ 0.5 \cdot 19.83/434.78) = 0.02 > 0.0116$
$v_{min} = 0.0525/1.5 \cdot 2^{3/2} \cdot 35^{0.5} = 0.586$ N/mm²
$v_{Rd,c} = 0.12 \cdot 2 \cdot (100 \cdot 0.01158 \cdot 35)^{1/3} = 0.824$ N/mm² > 0.586 N/mm²

1.066 N/mm² > 0.824 N/mm² ⇒ shear reinforcement required

maximal load-bearing resistance

$v_{Rd,max} = 1.4 \cdot v_{Rd,c}$

$v_{Rd,max} = 1.4 \cdot 0.824 = 1.154$ N/mm²

1.066 N/mm² < 1.154 N/mm² ⇒ $v_{Ed,crit}$ enabled to resist with shear reinforcement

basic value of the minimum shear reinforcement

$A_{sw,crit} = (v_{Ed} - 0.75 \cdot v_{Rd,c}) \cdot s_r \cdot u_1 / (1.5 \cdot f_{ywd,ef})$
$f_{ywd,ef} = 250 + 0.25 \cdot d \leq f_{ywd}$

$f_{ywd,ef} = 250 + 0.25 \cdot 190 = 297.5$ N/mm²
$f_{ywd} = 500/1.15 = 434.8$ N/mm² > 297.5 N/mm²
$s_r = 0.75 \cdot 19 = 14.3$ cm
$A_{sw,crit} = (1.066 - 0.75 \cdot 0.824) \cdot 14.3 \cdot 2.33/(1.5 \cdot 297.5) \cdot 100 = 3.33$ cm²

5. Design calculation

5.1. Stirrup reinforcement rows

$A_{sw,min} = \kappa_{sw} \cdot A_{sw,crit}$
$A_{sw,min} = 0.08/1.5 \cdot f_{ck}^{0.5}/f_{yk} \cdot s_r \cdot u$

bar diameter

max $\varnothing_{sw} \leq 0.05 \cdot 190 \approx 10$ mm ⇒ **selected Ø 10**

information on erection of 10er stirrups: both reinforcement layers have to be covered

Nr	κ_{sw} -	$A_{sw,min}$ cm²	s_r cm	l_w cm	u m	$A_{sw,min}$ cm²	min n -	selected leg	$\bar{s}_t$ cm	$A_{sw,exis}$ cm²
1	2.50	8.33	9.5	9.5	1.44	0.86	6	12 Ø 10	12.0	9.42
2	1.40	4.67	14.3	23.8	1.89	1.70	7	8 Ø 10	23.6	6.28
3	1.00	3.33	14.3	38.0	2.33	2.10	9	10 Ø 10	23.3	7.85
4	1.00	3.33	14.3	52.3	2.78	2.50	8	8 Ø 10	34.8	6.28

permitted spacing of link legs:

$s_t \leq 28.5$ cm in 1., 2. and 3. row
$s_t \leq 38.0$ cm in 4. row

information on the positional tolerance:
acc. to [2] radial deflection up to ±0.2d (here ±3.8cm) concerning theoretical section allowed.
for this it is important that the first row always lies between 0.3d and 0.5d.

κ_{sw} - adjustment factor acc. to [1], NCI to 6.4.5 (1) 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

$v_{Rd,c} = C_{Rd,c} \cdot k \cdot (100 \cdot \rho_{l,zug} \cdot f_{ck})^{1/3} \geq v_{min}$ [N/mm²]
$C_{Rd,c} = 0.15/\gamma_c$

perimeter of outer control perimeter

$l_{w,out} = 52.3 + 1.5 \cdot 19 = 80.8$ cm ⇒ $u_{out} = 3.68$ m

decisive shear stress

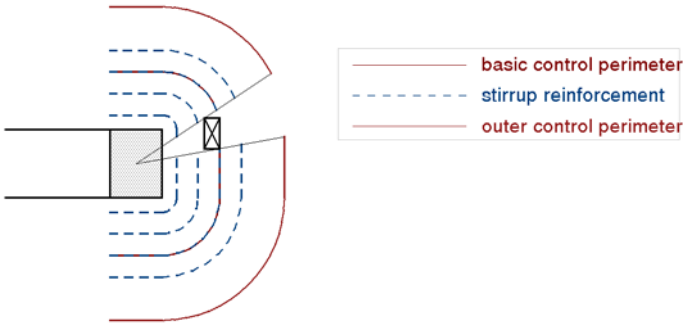
$v_{Ed,out} = 1.066 \cdot 2.33/3.68 = 0.676$ N/mm²

shear resistance

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

$v_{Rd,c} = 0.1 \cdot 2 \cdot (100 \cdot 0.01158 \cdot 35)^{1/3} = 0.687$ N/mm² > 0.586 N/mm²

0.676 N/mm² ≈ 0.687 N/mm² ⇒ Verification done



6. Minimum longitudinal reinforcement to ensure shear resistance

acc. to [3] table tab. NA.6.1.1

tension face	direction	η	$m_{Ed,min}$ kNm/m	$a_{so,min}$ cm²/m	$a_{su,min}$ cm²/m	distribution width m
top	x	0.125	43.75	5.22	----	0.30
	y	0.125	43.75	5.22	----	0.00

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

[1] DIN EN 1992-1-1/NA: Nationaler Anhang - National festgelegte Paramter - Eurocode 2, Teil 1-1, Januar 2011
[2] DAfStb Heft 525: Erläuterungen zu DIN 1045-1, 2. überarb. Aufl., Beuth, 2010
[3] DIN EN 1992-1-1: Eurocode 2: Bemessung und Konstruktion von Stahlbeton- und Spannbetontragwerken, Teil 1-1, Januar 2011