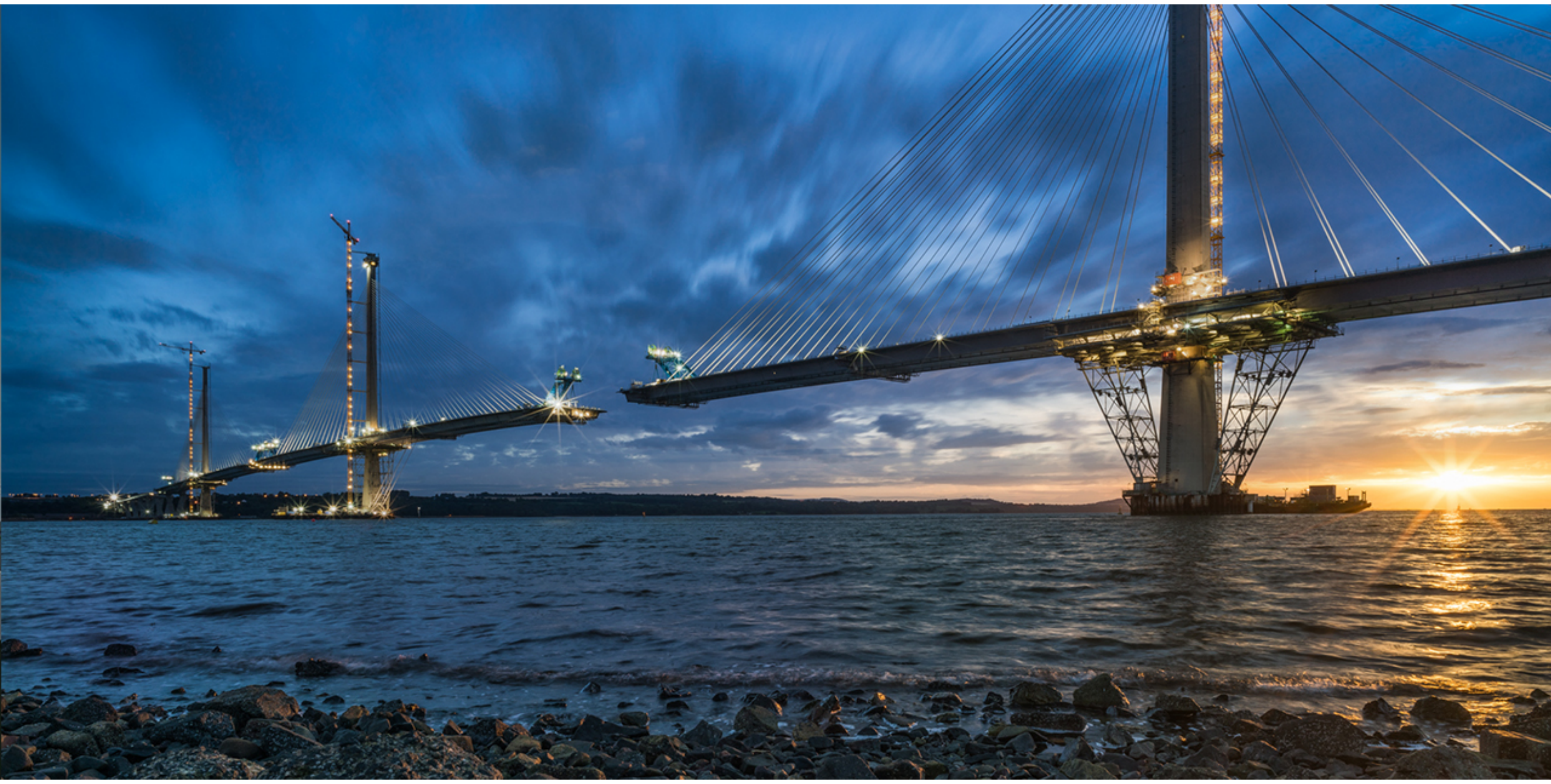
SOFiSTiK



Benchmark Example No. 31

Punching of flat slab acc. DIN EN 1992-1-1

SOFiSTiK | 2020

VERiFiCATiON
DCE-EN31 Punching of flat slab acc. DIN EN 1992-1-1

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Front Cover

Project: Queensferry Crossing | Photo: Bastian Kratzke

Overview	
Design Code Family(s):	DIN
Design Code(s):	DIN EN 1992-1-1
Module(s):	BEMESS
Input file(s):	punching_din_en_1992.dat

1 Problem Description

The problem consist of a flat slab of a multi-story building as shown in Fig. 1. The design of slab against punching at the columns is discussed in the following.

For the concrete, strength class C35/45 ($f_{ck} = 35\ MPa$, $\gamma_c = 1.5$) is assumed, for the reinforcing steel, grade B500B ($f_{yk} = 500\ MPa$, $E_s = 205\ GPa$, $\gamma_s = 1.15$, ductility class B). The factored design load accounting for self-weight, dead load and imposed load is $e_d = 14.67\ kN/m^2$.

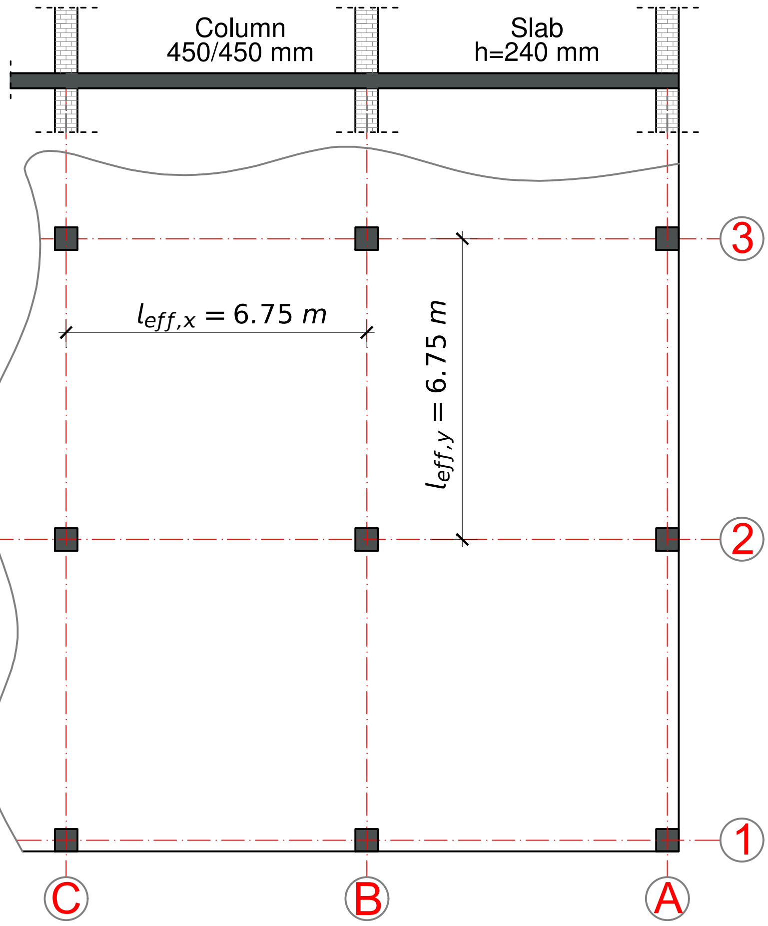

Figure 1: Model

2 Reference Solution

This example is concerned with the punching of flat slabs. The content of this problem is covered by the following parts of DIN EN 1992-1-1:2004 + AC:2010 [1]:

- Construction materials (Section 3)

- Punching (Section 6.4)

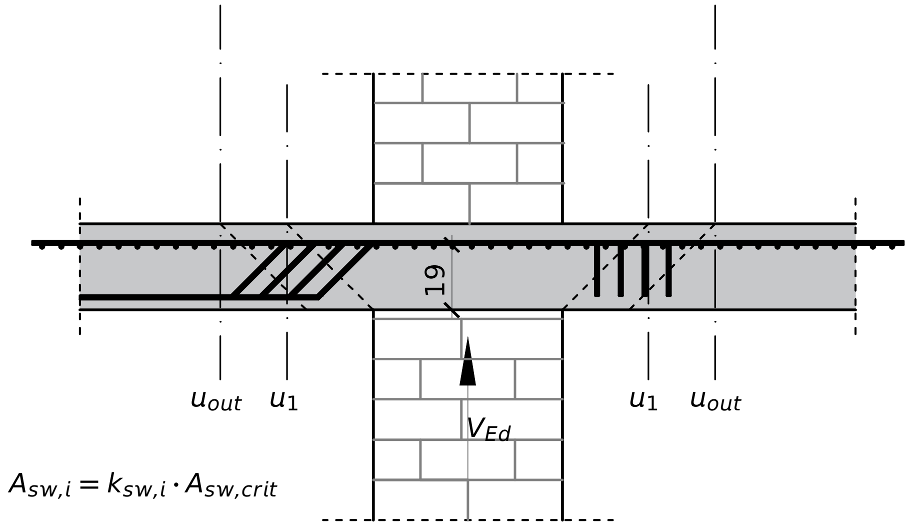

Figure 2: Punching

3 Model and Results

The goal of the preliminary design is to check if the dimensions of the structure are reasonable with respect to the punching shear strength and if punching shear reinforcement is required.

In the reference example the reaction forces are estimated by using contributive areas, therefore the example has been splitted into three models to show the punching for

- the inner column B2,
- the edge column A2/B1,
- wall at position B2.

The SOFiSTiK and reference results are given in Table 3.

Table 1: Results

Result	SOF.	Ref.
Inner column B2 (Node 1)		
V_{Ed} $[kN]$	808.0	809.0
$V_{Ed,red}$ $[kN]$	803.0	–
v_{Ed} $[N/mm^2]$	1.11	1.12
$v_{Rd,c}$ $[N/mm^2]$	0.93	0.93
$v_{Rd,max}$ $[N/mm^2]$	1.30	1.30
u_{out} $[m]$	6.01	6.05
u_1 $[m]$	4.188	4.19

Table 1: (continued)

Result	SOF.	Ref.
β	1.10	1.10
d $[m]$	0.19	0.19
Edge column B1/A2 (Node 2)		
V_{Ed} $[kN]$	317.5	319
$V_{Ed,red}$ $[kN]$	312.5	–
v_{Ed} $[N/mm^2]$	1.17	0.925
$v_{Rd,c}$ $[N/mm^2]$	0.86	0.86
$v_{Rd,max}$ $[N/mm^2]$	1.21	1.204
u_{out} $[m]$	3.21	3.28
u_1 $[m]$	2.539	2.54
β	1.40	1.40
d $[m]$	0.19	0.19
Wall B2 (Node 1014)		
V_{Ed} $[kN]$	360.8	381.0
$V_{Ed,red}$ $[kN]$	–	–
v_{Ed} $[N/mm^2]$	1.14	1.20
$v_{Rd,c}$ $[N/mm^2]$	0.88	0.878
$v_{Rd,max}$ $[N/mm^2]$	1.23	1.229
u_{out} $[m]$	3.50	3.69
u_1 $[m]$	2.244	2.24
β	1.35	1.35
d $[m]$	0.19	0.19

4 Design Process[1]

The calculation steps of the reference solution are presented below.

4.1 Material

3.1 Concrete

⊞ Concrete 35/45

Characteristic value of cylinder compressive strength

$f_{ck} = 35\ N/mm^2$

$$f_{cd} = \alpha_{cc} \cdot \frac{f_{ck}}{\gamma_c}$$

$$f_{cd} = 0.85 \cdot \frac{35}{1.5} = 19.80\ N/mm^2$$

3.2 Reinforcing steel

⊞ Steel B500B (flexural and transverse reinforcement)

3.2.2

$f_{yk} = 500\ MPa$

$$f_{yd} = \frac{f_{yk}}{\gamma_s} = 435.00\ N/mm^2$$

$E_s = 205000\ MPa$

Ductility class: B

4.2 Actions and Loads

Table 2: Characteristic actions

Action	Characteristic value kN/m^2
Dead-weight (g_k)	7.25
Variable load (q_k)	3.25

⊞ Combined loads for design:

$g_d = \gamma_G \cdot g_k = 1.35 \cdot 7.25 = 9.79\ kN/m^2$

$q_d = \gamma_Q \cdot q_{k,1} = 1.50 \cdot 3.25 = 4.88\ kN/m^2$

$e_d = g_d + q_d = 9.79 + 4.88 = 14.67\ kN/m^2$

4.3 Punching check for inner Column

⊞ Calculating effective depth d in x direction:

$$\begin{aligned} d_x &= h - c_{v,l} - 0.5 \cdot \phi \\ &= 240 - 30 - 10 \\ &= 200\ mm \end{aligned}$$

[1] The sections mentioned in the margins refer to DIN EN 1992-1-1 [1] unless otherwise specified.

⊞ Calculating effective depth d in y direction:

$$d_y = d_x - \phi$$
$$= 200 - 20$$
$$= 180\ mm$$

The columns will be checked for punching check:

$v_{Rd,c}$ without punching reinforcement

$v_{Rd,s}$ with punching reinforcement

$v_{Rd,max}$ check the maximum value of shear

The position of columns is shown in Fig 3.

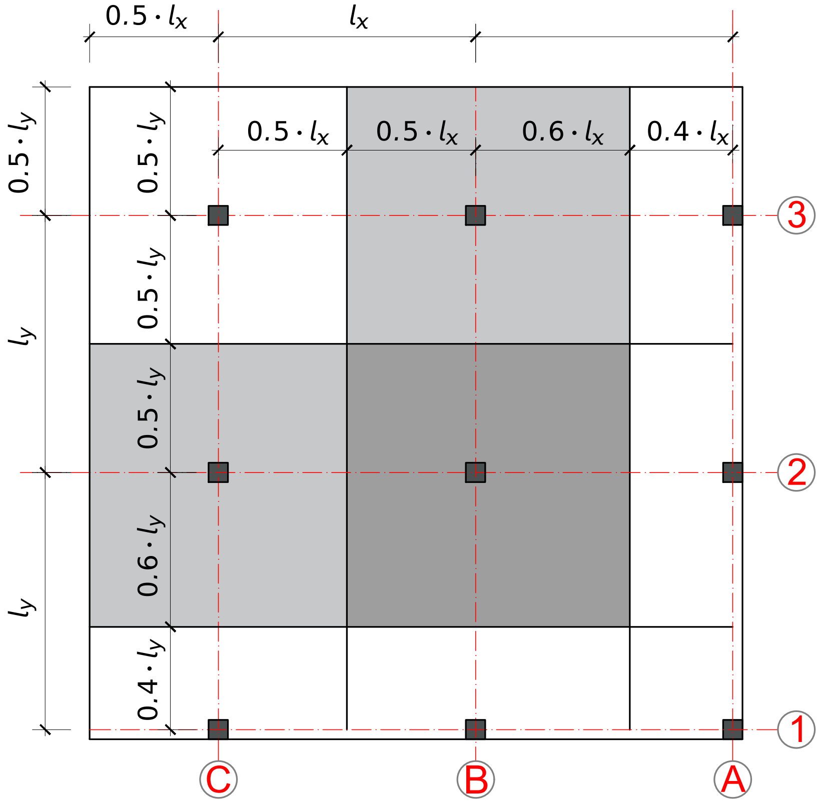

Figure 3: Load distribution - columns

Table 3: Load distribution per column

Column Type	Axis	Area $[m^2]$	V_{Ed} [kN]
Inner column	C/3	45.56	700.60
Inner column	B/3, C/2	50.12	745.80
Corner column	B/2	55.13	749.20
Edge column	A/3, C/1	19.74	298.60
Edge column	A/2, B/1	21.72	305.60

Table 3: (continued)

Column Type	Axis	Area $[m^2]$	V_{Ed} [kN]
Corner column	A/1	8.56	139.90

⊞ Effective depth d

$$d = \frac{d_x + d_y}{2}$$

$$d = \frac{0.2 + 0.18}{2}$$

$$d = 0.19\ m$$

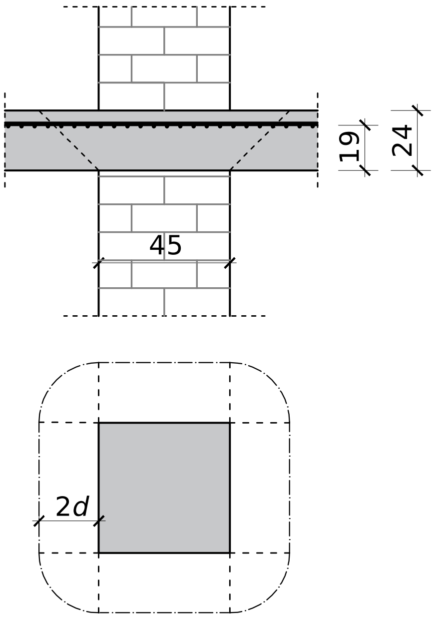

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Figure 4: Punching - inner column

⊞ Perimeter u_0 and u_1

$$u_0 = 4 \cdot 0.45 = 1.80\ m$$

$$u_1 = 2 \cdot (2 \cdot 0.45 + \pi \cdot 2.0 \cdot 0.19)$$

$$u_1 = 4.19\ m$$

⊞ Max. shear force (column B/2):

6.4.3, Eq. 6.38

$$v_{Ed} = \frac{\beta \cdot V_{Ed}}{u_i \cdot d}$$

$$V_{Ed} = 809\ kN$$

BEMESS is reducing the V_{Ed} value by dead load of the slab.

$V_{Ed,red} = V_{Ed} - V_{red}$

$V_{red} = 1.35 \cdot \gamma_c \cdot r^2_{col,eff} \cdot \pi \cdot h_{slab}$

Where:

$r_{col,eff}$ is the effective radius of the column

γ_c is the nominal weight of the concrete in kN/m^3

$r^2_{col,eff} \cdot \pi$ is the effective area

h_{slab} height of the slab

$A_{col} = a \cdot b$ or $A_{col} = a^2$ (if a=b)

$$r_{col,eff} = \sqrt{\frac{A_{col}}{\pi}}$$

$\beta = 1.10$

NDP, 6.4.3(6), $\beta = 1.1$ for inner columns

In BEMESS the β value is limited to $\beta_{max} = 1.8$.
Min. value is taken as $\beta_{min} = 1.1$

$1.1 \leq \beta \leq 1.8$

$$\beta = 1 + k \cdot \frac{M_{Ed}}{V_{Ed} \cdot \frac{u_1}{W_1}}$$

The W_i value is calculated acc. $W_i = \int_0^{u_i} |e| dl$

6.4.3, Eq. 6.39 and Eq. 6.40

$$v_{Ed} = \frac{0.809 \cdot 1.10}{4.19 \cdot 0.19} = 1.118 \ MN/m^2$$

Shear resistance without punching reinforcement

for $\frac{u_0}{d} = \frac{1.80}{0.19} = 9.5 > 4$

$$v_{Rd,c} = \frac{0.18}{\gamma_c} \cdot k \cdot (100 \cdot \rho_l \cdot f_{ck})^{1/3} + 0.1 \cdot \sigma_{cp} \geq v_{min} + 0.10 \cdot \sigma_{cp}$$

NDP, 6.4.4(1), Eq. 6.47, slabs without punching reinforcement

with:

$k = 1 + (200/d)^{1/2} \leq 2.0$

$k = 1 + (200/190)^{1/2} = 2.0$

$k > 2.0$, because $d = 190 \ mm < 200 \ mm$

$v_{min} = (0.0525/\gamma_c) \cdot k^{3/2} \cdot f_{ck}^{1/2}$

NCI, 6.2.2, Eq. 6.3DE for $d \leq 600$

$v_{min} = (0.05252/1.5) \cdot 2.0^{3/2} \cdot 35^{1/2} = 0.586 \ MN/m^2$

Reinforcement ratio for longitudinal reinforcement

over column B/2 - width of the strip

$b = 0.4 \cdot 6.75 \ m = 2.70 \ m > b_p = 0.45 + 2 \cdot 3.0 \cdot 0.19 = 1.59 \ m$

⊞ Reinforcement ratio

$$\rho_{l,x} = \frac{31.42}{100 \cdot 20} = 0.0157$$

$$\rho_{l,y} = \frac{31.42}{100 \cdot 18} = 0.0175$$

$$\begin{aligned}\rho_l &= (\rho_{l,x} \cdot \rho_{l,y})^{1/2} \\ &= (0.0157 \cdot 0.0175)^{1/2} \\ &= 0.0166 \\ &\leq 0.02 \\ &\leq 0.50 \cdot \frac{f_{cd}}{f_{yd}} = 0.5 \cdot \frac{19.8}{435} = 0.023\end{aligned}$$

$$v_{Rd,c} = \frac{0.18}{1.5} \cdot 2.0 \cdot (100 \cdot 0.0166 \cdot 35)^{1/3}$$

$$v_{Rd,c} = 0.928\ MN/m^2 > v_{min}$$

$$< v_{Ed} = 1.118\ MN/m^2$$

⇒ Punching reinforcement is required!

Slab with punching reinforcement

$$\begin{aligned}v_{Rd,max} &= 1.4 \cdot v_{Rd,c} \\ &= 1.4 \cdot 0.928 = 1.299\ MN/m^2 \\ &> v_{Ed} = 1.118\ MN/m^2\end{aligned}$$

$v_{Rd,max}$
(NDP) 6.4.5(3) Eq.(NA.6.53.1)

⇒ v_{Ed} the punching reinforcement can be used

Punching reinforcement $\alpha = 90°$

(NCI) for 6.4.5 (4): For $u_{out} \rightarrow v_{Rd,c}$ is used according to 6.2.2 (1), $C_{Rd,c} = 0.15/\gamma_c$ and not $0.18/\gamma_c$

$$u_{out} = \beta \cdot \frac{V_{Ed}}{v_{Rd,c} \cdot d}$$

$$u_{out} = 1.10 \cdot \frac{0.809}{0.928 \cdot \frac{0.15}{0.18} \cdot 0.19}$$

$$u_{out} = 6.05\ m$$

Loaded area perimeter A_{load}

$$\begin{aligned}a_{out} &= \frac{u_{out} - u_0}{2 \cdot \pi} \\ &= \frac{6.05 - 1.80}{2 \cdot \pi} \\ &= 0.67\ m \Rightarrow \approx 3.52 \cdot d\end{aligned}$$

The punching reinforcement is required until $(3.52 - 1.5) \cdot d = 2.02 \cdot d$

$$V_{Rd,cs} = 0.75 \cdot v_{rd,c} + 1.5 \cdot (d/s_r) \cdot \frac{A_{sw} \cdot f_{ywed,ef} \cdot sin\alpha}{u_1 \cdot d}$$

with:

$$f_{ywd,ef} = 250 + 0.25 \cdot d \leq f_{ywd}$$

$$f_{ywd,ef} = 250 + 0.25 \cdot 190 = 297\ MN/m^2 < 435\ MN/m^2$$

$$s_r = 0.75 \cdot d$$

$$A_{sw} = \frac{(v_{Ed} - 0.75 \cdot v_{Rd,c}) \cdot u_1 \cdot d}{1.5 \cdot \frac{d}{s_r} \cdot f_{ywd,ef}}$$

$$A_{sw} = \frac{(1.118 - 0.75 \cdot 0.928) \cdot 4.19 \cdot 0.19}{1.5 \cdot \frac{1}{0.75} \cdot 297} \cdot 10^4$$

$$A_{sw} = 5.66\ cm^2$$

Reinforcement in perimeter 1 - $A_{sw,1}$

$$_{req}A_{sw,1} = k_{sw} \cdot A_{sw}$$

$$_{req}A_{sw,1} = 2.5 \cdot 5.66 = 14.10\ cm^2$$

Reinforcement in perimeter 2 - $A_{sw,2}$

$$_{req}A_{sw,2} = k_{sw} \cdot A_{sw}$$

$$_{req}A_{sw,2} = 1.4 \cdot 5.66 = 7.92\ cm^2$$

Detailing of reinforcement

The spacing of link legs around a perimeter should not exceed $1.5 \cdot d$ within the first control perimeter ($2 \cdot d$ from loaded area), and should not exceed $2 \cdot d$ for perimeters outside the first control perimeter where that part of the perimeter is assumed to contribute to the shear capacity.

$$u_{s1} = 2.40\ m \Rightarrow \min n = \frac{2.40}{1.5 \cdot 0.19} = 9$$

$$u_{s2} = 3.29\ m \Rightarrow \min n = \frac{3.29}{1.5 \cdot 0.19} = 12$$

Min. punching reinforcement:

$$A_{sw,min} = \frac{0.08}{1.5} \cdot \frac{\sqrt{f_{ck}}}{f_{yk}} \cdot s_r \cdot s_t$$

(NCI), 9.4.3: Eq. (9.11DE)

$$A_{sw,min} = 0.05333 \cdot \frac{\sqrt{35}}{500} \cdot 0.75 \cdot 1.5 \cdot 1.9^2$$

$$A_{sw,min} = 0.26\ cm^2$$

4.4 Punching check for edge column

The punching check for columns (A2/B1) is verified:

Slab: C35/45, $d = 0.19\ m$

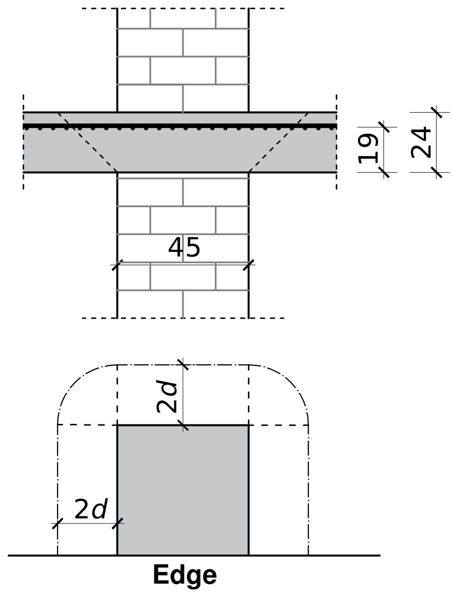

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Figure 5: Punching - edge column B1/A2

⊞ Critical perimeter

$u_1 = 3 \cdot 0.45 + \pi \cdot 2.0 \cdot 0.19$

$u_1 = 2.54\ m$

For edge and corner columns the effective perimeter is reduced based by using the *Sector Method* (See Fig. 6). The *Sector Method* delivers the effective perimeter u of the punching round cut. The ratio u/u_0 is output in % in the result list.

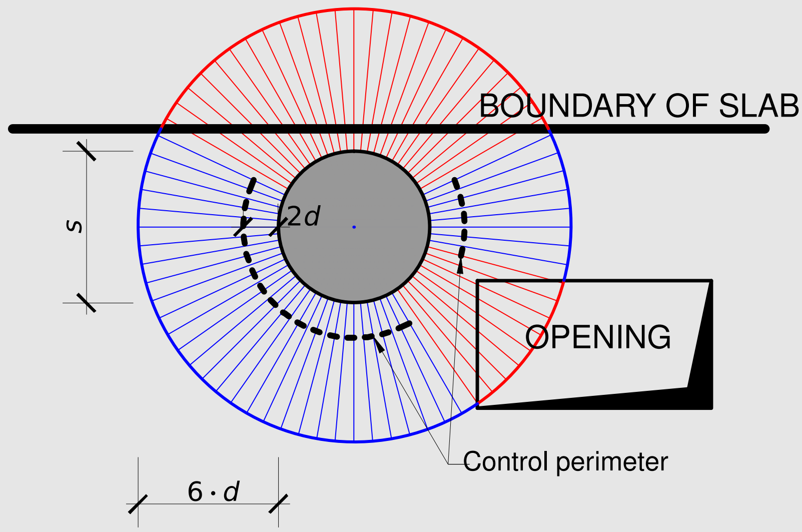


Figure 6: Calculating the control perimeter near opening by using "Sector Method"

⊞ Maximal shear force:

$V_{Ed} = 319\ kN$

$$v_{Ed} = \frac{\beta \cdot V_{Ed}}{u_i \cdot d}$$

v_{Ed}, 6.4.3, Eq. 6.38

$\beta = 1.4$

NDP, 6.4.3(6), $\beta = 1.4$ for edge columns

$$v_{Ed} = \frac{1.40 \cdot 0.319}{2.54 \cdot 0.19}$$

$v_{Ed} = 0.925\ MN/m^2$

Shear resistance without punching reinforcement

$$v_{Rd,c} = \frac{0.18}{\gamma_c} \cdot k \cdot (100 \cdot \rho_l \cdot f_{ck})^{1/3} \geq v_{min}$$

NDP, 6.4.4(1), Eq. 6.47, slabs without punching reinforcement

with

$k = 2.0$

$v_{min} = 0.586\ MN/m^2$

v_{min}, NCI, 6.2.2, Eq. 6.3DE for $d \leq 600$

⊞ Reinforcement ration ρ_l:

(Parallel over the edge of column B/1)

$$\rho_{lx} = \frac{20.11}{100 \cdot 20} = 0.01$$

$$\rho_{ly} = \frac{31.42}{100 \cdot 18} = 0.0175$$

$$\rho_l = (0.01 \cdot 0.0175)^{1/2} = 0.0132$$
$$\leq 0.02$$
$$\leq 0.50 \cdot \frac{f_{cd}}{f_{yd}} = 0.023$$

$$v_{Rd,c} = \frac{0.18}{1.5} \cdot 2.0 \cdot (100 \cdot 0.0132 \cdot 35)^{1/3}$$

$$v_{Rd,c} = 0.860\ MN/m^2 > v_{min}$$
$$< 0.925\ MN/m^2$$

⇒ punching reinforcement is required!

Slab with punching reinforcement

⊞ Maximum shear force

$$v_{Rd,max} = 1.4 \cdot v_{Rd,c} = 1.4 \cdot 0.860$$
$$= 1.204\ MN/m^2 > V_{Ed} = 0.925\ MN/m^2$$

$v_{Rd,max}$ (NDP) 6.4.5(3) Eq.(NA.6.53.1)

⇒ the punching reinforcement can bear the shear force v_{Ed}!

Punching reinforcement $\alpha = 90°$

(NCI) for 6.4.5 (4): For $u_{out} \rightarrow v_{Rd,c}$ is used according to 6.2.2 (1), $C_{Rd,c} = 0.15/\gamma_c$ and not $0.18/\gamma_c$

$$u_{out} = \beta \cdot \frac{V_{Ed}}{v_{Rd,c} \cdot d}$$

$$u_{out} = 1.4 \cdot \frac{0.319}{0.860 \cdot \frac{0.15}{0.18} \cdot 0.19}$$

$$u_{out} = 3.28\ m$$

⊞ Loaded area perimeter A_{load}

$$a_{out} = \frac{u_{out} - u_o}{\pi} = \frac{3.28 - 3 \cdot 0.45}{\pi} = 0.61\ m \rightarrow \approx 3.21 \cdot d$$

Punching reinforcement is required until $(3.21 - 1.5) \cdot d = 1.71 \cdot d$

$$v_{Rd,s} = 0.75 + v_{Rd,c} + 1.5 \cdot \frac{d}{s_r} \cdot \frac{A_{sw} \cdot f_{ywd,ef} \cdot sin\alpha}{u_1 \cdot d}$$

with

$$f_{ywd,ef} = 297\ MN/m^2$$

$$s_r = 0.5 \cdot d$$

$$A_{sw} = (v_{Ed} - 0.75 \cdot v_{R,dc}) \cdot \frac{u_1 \cdot d}{1.5 \cdot \frac{d}{s_r} \cdot f_{ywd,ef}}$$

$$A_{sw} = (0.925 - 0.75 \cdot 0.860) \cdot \frac{2.54 \cdot 0.19 \cdot 10^4}{1.5 \cdot \frac{1}{0.5} \cdot 297}$$

$$A_{sw} = 1.51\ cm^2$$

Reinforcement in perimeter 1 - $A_{sw,1}$

$$_{req}A_{sw,1} = k_{sw} \cdot A_{sw}$$

$$_{req}A_{sw,1} = 2.5 \cdot 1.51 = 3.79\ cm^2$$

Reinforcement in perimeter 2 - $A_{sw,2}$

$$_{req}A_{sw,2} = k_{sw} \cdot A_{sw}$$

$$_{req}A_{sw,2} = 1.4 \cdot 1.51 = 2.12\ cm^2$$

(NCI), 9.4.3: Eq. (9.11DE)

$$A_{sw,min} = 0.26\ cm^2$$

4.5 Punching check for wall

The punching check is verified at position B2.

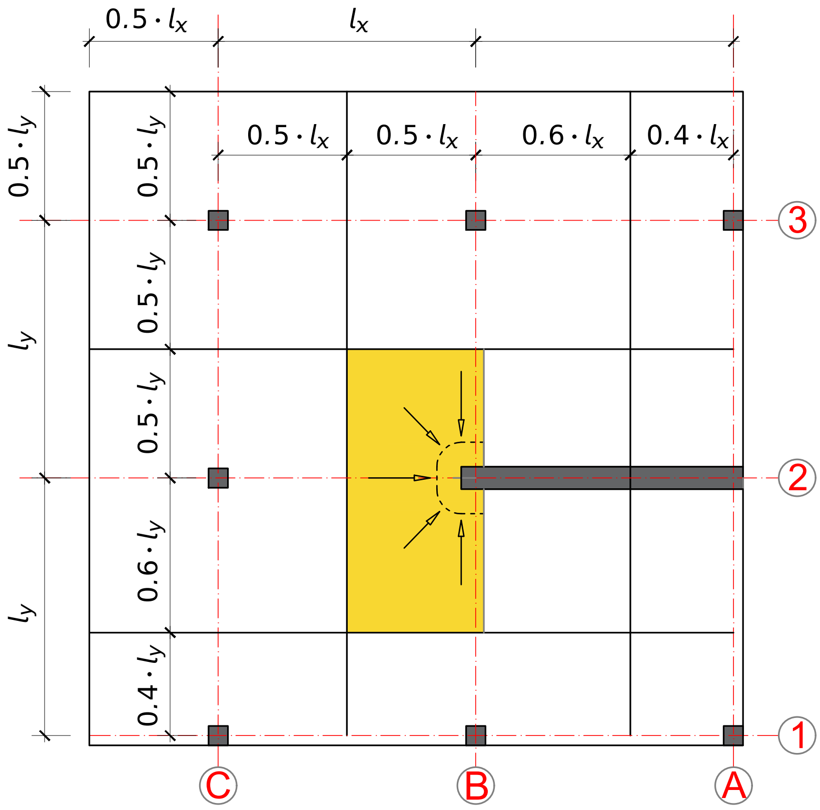
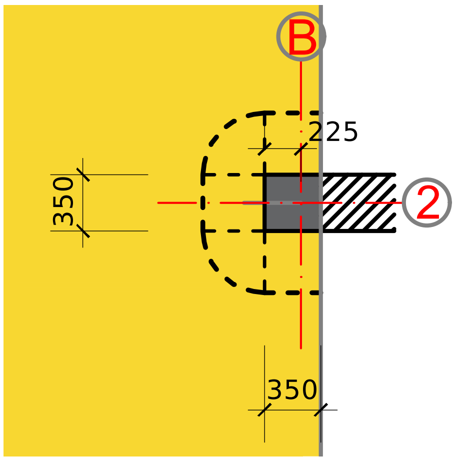


Figure 7: Load distribution - wall

$d = 190\ mm$

$b_1 = b = 350\ mm < 3 \cdot d$

$$\frac{a_1}{2} = b = 350\ mm$$
$$< 3 \cdot d - 0.5 \cdot b_1 = 3 \cdot 190 - 175 = 395\ mm$$



$e_d = 14.67\ kN/m^2$

Load distribution:

$$A_{LE} = (0.5 + 0.6) \cdot 6.75\ m \cdot (0.5 \cdot 6.75\ m + 0.125\ m) = 26.0\ m^2$$

$$V_{Ed} = A_{LE} \cdot e_d$$

$$V_{Ed} = 26.0 \cdot 14.67 = 381\ kN$$

For walls there are two methods to analyse the punching force at wall ends and corners. Default is the integration of the slab shear force along the critical perimeter. As the result varies depending on the distance to the wall, BEMESS analyses four distances and takes the maximum punching force.

Critical perimeter:

$$u_1 = 3 \cdot 0.35 + \phi \cdot 2.0 \cdot 0.19 = 2.24\ m$$

Max. shear force:

$$v_{Ed} = \frac{\beta \cdot V_{Ed}}{u_i \cdot d}$$

$\beta = 1.35$ for wall ending, (NDP) 6.4.3 (6)

$$\beta = 1.35$$

$$v_{Ed} = \frac{1.35 \cdot 0.381}{2.24 \cdot 0.19} = 1.208\ MN/m^2$$

Shear resistance without punching reinforcement

NDP, 6.4.4(1), Eq. 6.47, slabs without punching reinforcement

$$v_{Rd,c} = \frac{0.18}{\gamma_c} \cdot k \cdot (100 \cdot \rho_l \cdot f_{ck})^{1/3} \geq v_{min}$$

with:

$$k = 2.0$$

v_{min}; (NCI) 6.2.2; Eq. 6.3DE for $d \leq 600\ mm$

$$v_{min} = 0.586\ MN/m^2$$

⊞ Reinforcement ration ρ_l:

(Parallel over the edge of wall B/2)

For this example we will take $\rho_l = 1.4$ %

$$\rho_l = 0.014$$
$$\leq 0.02$$
$$\leq 0.50 \cdot \frac{f_{cd}}{f_{yd}} = 0.023$$

$$v_{Rd,c} = \frac{0.18}{1.5} \cdot 2.0 \cdot (100 \cdot 0.0140 \cdot 35)^{1/3}$$
$$v_{Rd,c} = 0.878\ MN/m^2 > v_{min}$$
$$< 1.208\ MN/m^2$$

⇒ punching reinforcement is required!

Slab with punching reinforcement

⊞ Maximum shear force

$$V_{Rd,max} = 1.4 \cdot v_{Rd,c} = 1.4 \cdot 0.878$$
$$= 1.229\ MN/m^2 < V_{Ed} = 1.208\ MN/m^2$$

$v_{Rd,max}$
(NDP) 6.4.5(3) Eq.(NA.6.53.1)

$\Rightarrow V_{Ed} < V_{Rd,max}$!

Punching reinforcement $\alpha = 90°$

(NCI) for 6.4.5 (4): $v_{Rd,c}$ is used according 6.2.2 (1), $C_{Rd,c} = \frac{0.15}{\gamma_c}$

$$u_{out} = \beta \cdot \frac{V_{Ed}}{v_{Rd,c} \cdot d}$$

$$u_{out} = 1.35 \cdot \frac{0.381}{0.878 \cdot \frac{0.15}{0.18} \cdot 0.19}$$

$$u_{out} = 3.69\ m$$

⊞ Loaded area perimeter A_{load}

$$a_{out} = \frac{u_{out} - u_o}{\pi}$$
$$= \frac{3.69 - 3 \cdot 0.35}{\pi} = 0.84\ m \rightarrow \approx 4.42 \cdot d$$

Punching reinforcement is required until $(4.42 - 1.5) \cdot d = 2.92 \cdot d$

$$v_{Rd,s} = 0.75 + v_{Rd,c} + 1.5 \cdot \frac{d}{s_r} \cdot \frac{A_{sw} \cdot f_{ywd,ef} \cdot sin\alpha}{u_1 \cdot d}$$

with

$$f_{ywd,ef} = 297\ MN/m^2$$

$$s_r = 0.5 \cdot d$$

$$A_{sw} = (v_{Ed} - 0.75 \cdot v_{R,dc}) \cdot \frac{u_1 \cdot d}{1.5 \cdot \frac{d}{s_r} \cdot f_{ywd,ef}}$$

$$A_{sw} = (1.208 - 0.75 \cdot 0.878) \cdot \frac{2.24 \cdot 0.19 \cdot 10^4}{1.5 \cdot \frac{1}{0.5} \cdot 297}$$

$$A_{sw} = 2.62\ cm^2$$

Reinforcement in perimeter 1 - $A_{sw,1}$

$${}_{req}A_{sw,1} = k_{sw} \cdot A_{sw}$$

$${}_{req}A_{sw,1} = 2.5 \cdot 2.62 = 6.55\ cm^2$$

Reinforcement in perimeter 2 - $A_{sw,2}$

$${}_{req}A_{sw,2} = k_{sw} \cdot A_{sw}$$

$${}_{req}A_{sw,2} = 1.4 \cdot 2.62 = 3.66\ cm^2$$

(NCI), 9.4.3: Eq. (9.11DE) $A_{sw,min} = 0.26\ cm^2$

5 Conclusion

The program searches for the single support nodes (single columns, wall ends as well as wall corners), and performs a punching check for these points. Nodes with less than 5 kN support reaction are not considered! Because the focus of the verification example is punching, the value ρ_l is overtaken from the verification example.

It has been shown that the results are reproduced with excellent accuracy.

6 Literature

[1] *DIN EN 1992-1-1/NA: Eurocode 2: Design of concrete structures, Part 1-1/NA: General rules and rules for buildings - German version EN 1992-1-1:2005 (D), Nationaler Anhang Deutschland - Stand Februar 2010*. CEN. 2010.

[2] *Beispiele zur Bemessung nach Eurocode 2 - Band 1: Hochbau*. Ernst & Sohn. Deutschen Beton- und Bautechnik-Verein E.V. 2011.