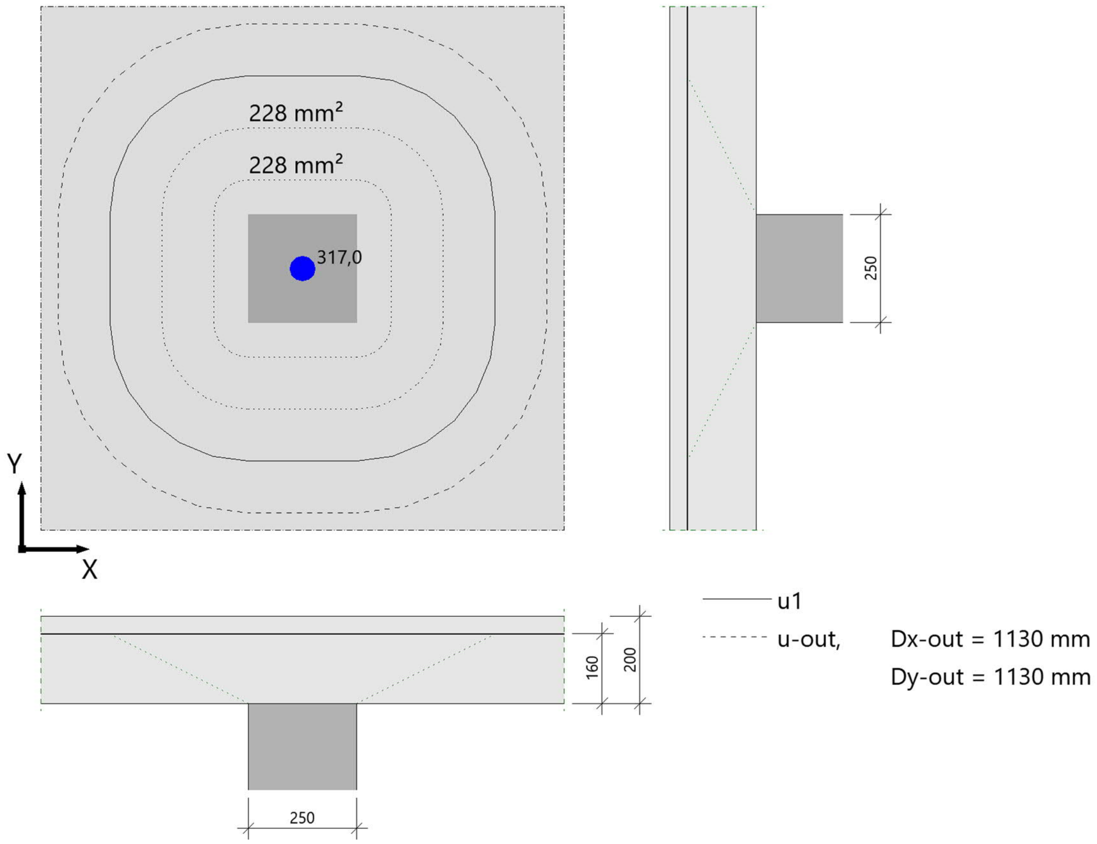
# Item: B6_001_Hand_Calculation_BS_EN_1992

Punching Shear Analysis (x64) B6+ 02/22B (FRILO R-2022-2/P06)

Click on the blue numbered buttons to jump to the associated Output/Hand calculated position

## System

Graphics




Geometry and Material

| | | | | | | |
|---|---|---|---|---|---|---|
| Slab | $h$ = | 200 mm | | $d_m$ = | 160 mm |
| Intern. column | $c_x$ = | 250 mm | | $c_y$ = | 250 mm |
| Concrete covering | $c_u$ = | 20 mm | | $c_o$ = | 20 mm |

| | | | | | |
|---|---|---|---|---|---|
| Materials | Concrete: | C 20/25 | Steel: | B 500A |
| | $\gamma_c$ = | 1.50 | $\gamma_s$ = | 1.15 |
| | $f_{ck}$ = | 20.0 N/mm² | $f_{yk}$ = | 500.0 N/mm² |

## Loads

Given shear force $V_E$ = 317.0 kN (= $V_{Ed}$)
Increase $\beta$ = 1.150

## Results

Punching through NA to BS EN 1992-1-1/A2:2015-07, CHECK for a flat slab acc.to par. 6.4

Loaded area perimeter $u_0$ = 1000 mm (at a= 0 mm)
Design shear force $v_{Ed,u0}$ = 2.278 N/mm² 5
max. design resistance $v_{Rd,max}$ = 3.680 N/mm²

basic control perimeter $u_1$ = 3011 mm (at a= 320 mm) 2

| | | | | |
|---|---|---|---|---|
| Design shear force | $v_{Ed}$ | = | 0.757 | N/mm² (3) |
| Prefactor | $C_{Rd,c}$ | = | 0.120 | |
| Scale factor | k | = | 2.000 | |
| Design resistance | $v_{Rd,c}$ | = | 0.643 | N/mm² (4) |
| | $v_{min}$ | = | 0.443 | N/mm² |

Result: $v_{Rd,c} < v_{Ed} \leq 2 * v_{Rd,c}$, $v_{Ed,u0} \leq v_{Rd,max}$ Punching shear reinforcement required

Longitudinal reinforcement ratio (**ρ** per direction) :

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| without punching reinforcement | reqρ | = | 1.568 | % | = | 2509 | mm²/m |
| max. reinforc. ratio | permρ | ≤ | 2.000 | % | = | 3200 | mm²/m (1) |
| exist reinforc. ratio | existρ | = | 0.963 | % | = | 1541 | mm²/m |

Reinforced areas :

| | | | | |
|---|---|---|---|---|
| cal. reinforcement width | cal $b_q$ | = | 1000 | mm |
| required installation width in the y-direction for $A_{sx}$ | req $b_{qy}$ | ≥ | 1210 | mm |
| required installation width in the x-direction for $A_{sy}$ | req $b_{qx}$ | ≥ | 1210 | mm |

outer control perimeter :

| | | | | | |
|---|---|---|---|---|---|
| outer control perimeter | $l_{out}$ | = | 440 | mm | ($l_r$+1.5*$d_m$) |
| Length of perimeter | $u_{out}$ | = | 3765 | mm | (7) |
| Design shear force | $v_{Ed}$ | = | 0.605 | N/mm² | |
| Design resistance | $v_{Rd,c}$ | = | 0.643 | N/mm²> $v_{Ed}$OK | |
| | $v_{min}$ | = | 0.443 | N/mm² | |

RESULT : punching sh. reinf.B 500A, $f_{ywd,ef}$ = 290.0 N/mm², **α** = 90°, $s_r$ = 120 mm

| Row [-] | $s_r$ [mm] | $l_r$ [mm] | u [mm] | req. $A_{sw}$ [mm²] | req. $A_{sw}$ [mm²/m] (6) | min. $A_{sw}$ [mm²] |
|---|---|---|---|---|---|---|
| 1 | 80 | 80 | 1503 | 228 | 152 | 57 |
| 2 | 120 | 200 | 2257 | 228 | 101 | 129 |
| Note: Bar diameter $d_s$ ≤ 8 mm (punching shear reinforcement) (8) | | | | | | |

The longitudinal reinforcement is to be anchored outside the outermost perimeter.

# Calculation by hand

## Geometry and loading

| | | |
|---|---|---|
| Slap depth | | = 200 mm |
| Static height | $d_m$ | = 160 mm |
| Column thickness and width | $c_x/c_y$ | = 250/250 mm |
| Loading: | $V_{Ed}$ | = 317 kN |

## Reinforcement ratio slab averaged (EN 1992 (6.4.4):

$$\rho_{l=}\sqrt{\rho_{lz}\cdot\rho_{ly}} = \frac{a_s}{A_c\cdot d} = \frac{154}{100\cdot 160} = 0{,}0096$$ 1

$$< \begin{cases} 0{,}02 \\ 0{,}4\cdot\frac{f_{cd}}{f_{yd}} = 0{,}4\cdot\frac{11{,}33}{435} = 0{,}010 \end{cases}$$

## Basic control perimeter (EN 1992 (6.4):

Distance from loaded area: $r = 2{,}0 \cdot d_m = 2{,}0 \cdot 160 = 320$ mm

Length of the basic control perimeter: $u1 = 4 \cdot a + 2 \cdot \pi \cdot r = 4 \cdot 250 + 2 \cdot \pi \cdot 320 = 3011$ mm 2

## Maximum punching shear stress at the control perimeter (6.4.3):

$$v_{Ed,u1} = \frac{\beta\cdot V_{Ed}}{u_1\cdot d} = \frac{1{,}15\cdot 317}{3{,}01\cdot 0{,}16} = 757{,}0\,\frac{kN}{m^2} = 0{,}757\ MN/m^2 \qquad (6.38)$$ 3

## Punching shear resistance without shear reinforcement (6.4.4):

$$v_{Rd,c} = C_{Rd,c}\cdot k\cdot(100\cdot\rho_l\cdot f_{ck})^{\frac{1}{3}} + k_1\cdot\sigma_{cp} \geq (v_{min} + k_1\cdot\sigma_{cp}) \qquad (6.47)$$

$$k = 1 + \sqrt{\frac{200}{d}} = 1 + \sqrt{\frac{200}{160}} \leq 2{,}0$$

$$v_{Rd,c} = \frac{0{,}18}{1{,}5}\cdot 2{,}0\cdot(100\cdot 0{,}0096\cdot 20)^{\frac{1}{3}} + 0 = 0{,}643\ MN/m^2$$ 4

$$v_{min} = 0{,}035\cdot k^{\frac{3}{2}}\cdot f_{ck}^{\frac{1}{2}} = 0{,}035\cdot 2{,}0^{\frac{3}{2}}\cdot 20^{\frac{1}{2}} + 0 = 0{,}443\ MN/m^2$$

$$v_{Ed,u1} = 0{,}757\,\frac{MN}{m^2} > v_{Rd,c} = 0{,}643\,\frac{MN}{m^2}$$

Shear reinforcement required.

## Punching shear resistance with shear reinforcement (6.4.5):

Evidence of maximum punching shear resistance $v_{Rd,max}$

$$v_{Ed} = \frac{\beta \cdot V_{Ed}}{u_0 \cdot d} = \frac{1{,}15 \cdot 317}{4 \cdot 0{,}25 \cdot 0{,}16} = 2278{,}4 \frac{KN}{m^2} = 2{,}278\ MN/m^2$$

5

$$v_{Rd,max} = 0{,}5 \cdot \nu \cdot f_{cd}$$

$$\nu = 0{,}6 \cdot \left[1 - \frac{f_{ck}}{250}\right] = 0{,}6 \cdot \left[1 - \frac{20}{250}\right] = 0{,}552$$

$$f_{cd} = \frac{f_{ck}}{\gamma_C} = \frac{20}{1{,}5} = 13{,}3\ MN/m^2$$

$$v_{Rd,max} = 0{,}5 \cdot 0{,}552 \cdot 13{,}3 = 3{,}68\ MN/m^2$$

$$v_{Ed} \leq v_{Rd,max}$$

Required shear reinforcement

$$v_{Rd,cs} = 0{,}75 \cdot v_{Rd,cs} + 1{,}5 \cdot \left(\frac{d}{s_r}\right) \cdot A_{sw} \cdot f_{ywd,ef} \cdot \left(\frac{1}{u_1 \cdot d}\right) \cdot sin\alpha \qquad (6.52)$$

$$f_{ywd.ef} = \min \begin{cases} 250 + 0{,}25 \cdot d = 250 + 0{,}25 \cdot 160 = 290 \dfrac{N}{mm^2} \\ f_{ywd} = 435\ N/mm^2 \end{cases}$$

For $v_{Ed} = v_{Rd,cs}$ after rearranging the equation (6.52)

$$A_{sw} = \frac{(v_{Ed} - 0{,}75 \cdot v_{Rd,c}) \cdot d \cdot u_1}{1{,}5 \cdot \left(\frac{d}{s_r}\right) \cdot f_{ywd,ef} \cdot sin\alpha} = \frac{(0{,}757 - 0{,}75 \cdot 0{,}643) \cdot 160 \cdot 3010}{1{,}5 \cdot \left(\frac{160}{0{,}75 \cdot 160}\right) \cdot 290 \cdot 1{,}0} = 228{,}1\ mm^2 = 2{,}28\ cm^2$$

6

## Control perimeter $u_{out}$, at which shear reinforcement is not required

$$req.u_{out} = \frac{\beta \cdot V_{Ed}}{v_{Rd,c} \cdot d} \ (6.54)$$

$$v_{Rd,c} = C_{Rd,c} \cdot k \cdot (100 \cdot \rho_l \cdot f_{ck})^{1/3} = \frac{0{,}18}{1{,}5} \cdot 2{,}0(100 \cdot 0{,}0096 \cdot 20)^{1/3} = 0{,}643\ MN/m^2 \qquad (6.2)$$

$$req.u_{out} = \frac{1{,}15 \cdot 0{,}317}{0{,}643 \cdot 0{,}16} = 3{,}55\ m = 3550\ mm$$

## Arrangement of the shear reinforcement (9.4.3)

### Radial

| | | | | | |
|---|---|---|---|---|---|
| 1.Row: 0,5 | ·d | from loaded area: | 0,5 | ·160 = | 80 mm |
| 2.Row: 0,75 | ·d | from loaded area: | 0,75 | ·160 = | 120 mm |
| Distance from second row to $u_{out:}$ 1,5·d= | | | 1,5 | ·160 = | 240 mm |

8

Existing $u_{out} = 4 \cdot a + 2 \cdot \pi \cdot r = 4 \cdot 250 + 2 \cdot \pi \cdot (0{,}5 + 0{,}75 + 1{,}5) \cdot 160 =$ 3765 mm > 3550 mm

7