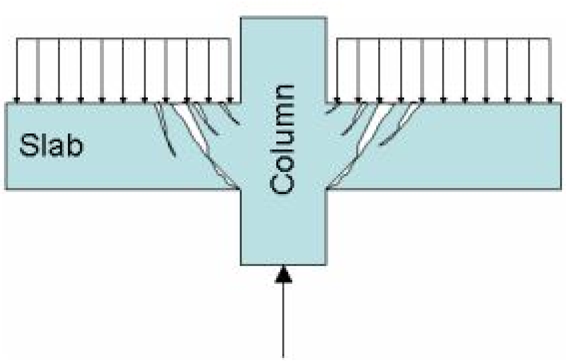

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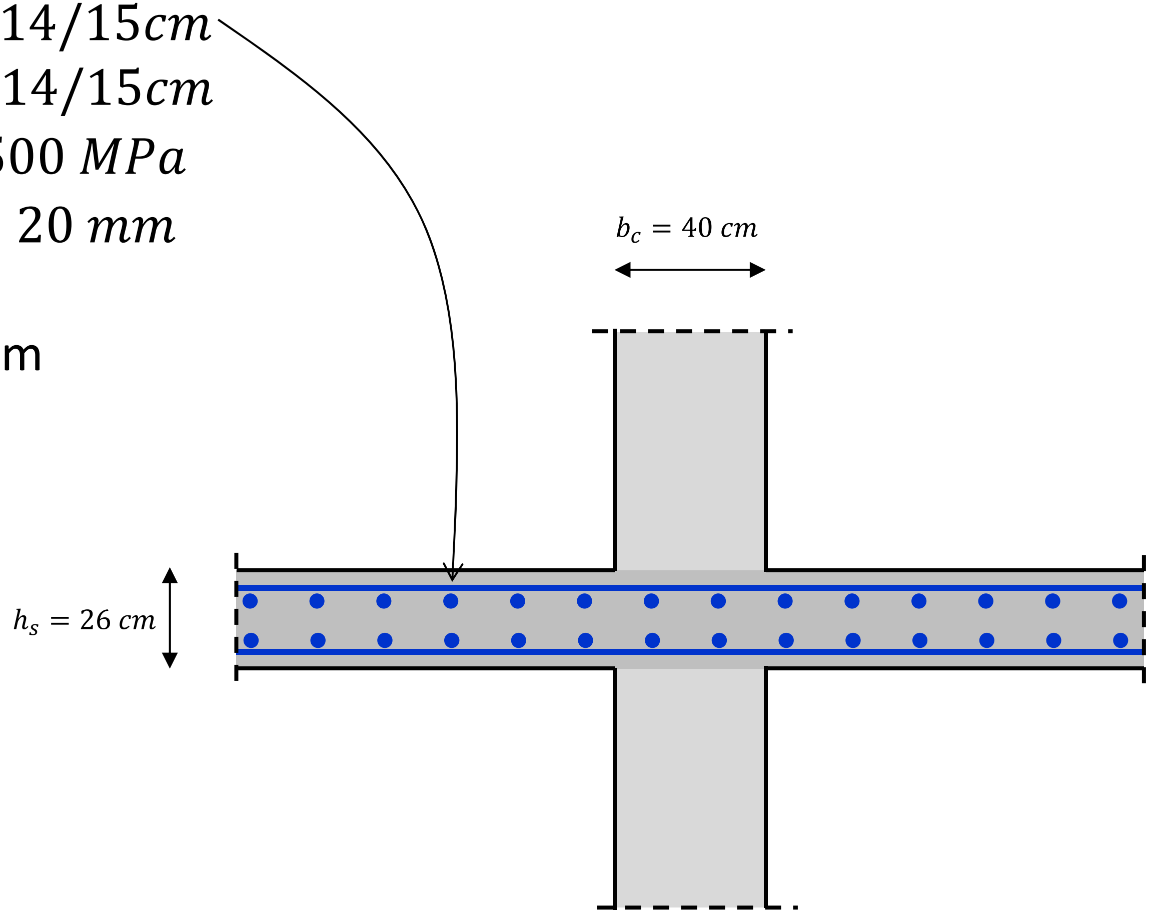
Initial data

Flat slab

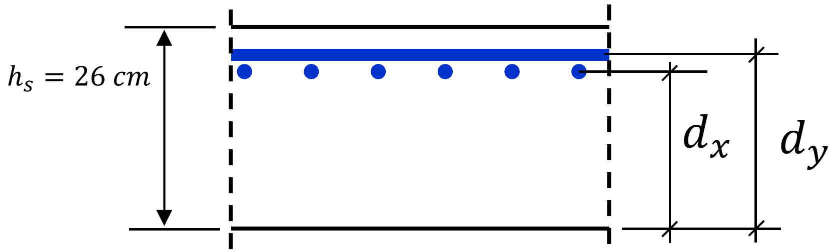
Thickness	$h_s = 26\ cm$
Concrete class	C30/37
Reinforcement	$A_x = \emptyset 14/15cm$
	$A_y = \emptyset 14/15cm$
Shear reinforcement	$f_{yk} = 500\ MPa$
Concrete cover	$c_{nom} = 20\ mm$

Interior column 40x40 cm

$V_{Ed} = 850\ kN$



Computation of the effective depth

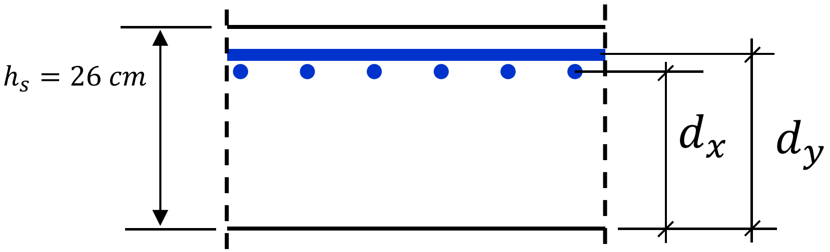


$$c_x = 20 + \frac{14}{2} = 27\ mm \quad \rightarrow \quad d_x = ?$$

$$c_y = 20 + 14 + \frac{14}{2} = 41\ mm \quad \rightarrow \quad d_y = ?$$

$$\rightarrow \quad \mathrm{d} = \frac{d_x}{2} + \frac{d_y}{2} = ?\ mm$$

Computation of the effective depth



$$c_x = 20 + \frac{14}{2} = 27\ mm \quad \rightarrow \quad d_x = 260 - 27 = 233\ mm$$

$$c_y = 20 + 14 + \frac{14}{2} = 41\ mm \quad \rightarrow \quad d_y = 260 - 41 = 219\ mm$$

$$\rightarrow \quad \mathrm{d} = \frac{d_x}{2} + \frac{d_y}{2} = 226\ mm$$

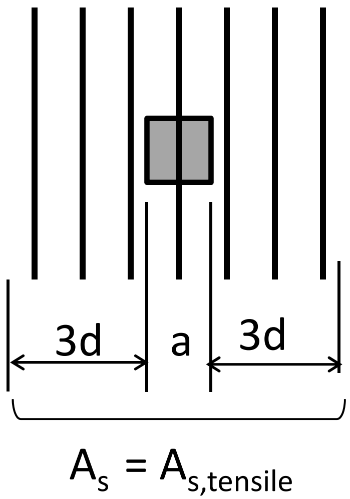
Longitudinal reinforcement coefficient

→ should be calculated as mean values taking into account a slab width equal to the column width plus 3*d* each side, see #6.4.4

$$A_x = A_y = \frac{\pi \cdot \emptyset^2}{4} \cdot \frac{b_c + 2 \cdot 3d}{s} = ?\, mm^2$$

$$\rho_{l,x} = \rho_{l,y} = \frac{A_x}{b \cdot d} = ?$$

$$\rho = \frac{A_s}{(6d + a)d}$$



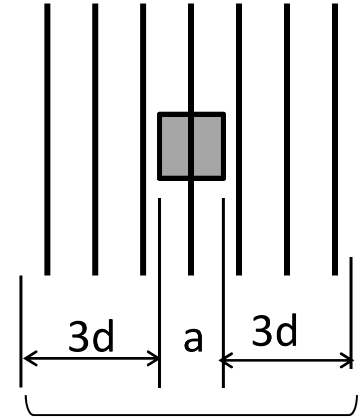
Longitudinal reinforcement coefficient

→ should be calculated as mean values taking into account a slab width equal to the column width plus 3*d* each side, see #6.4.4

$$A_x = A_y = \frac{\pi \cdot \varnothing^2}{4} \cdot \frac{b_c + 2 \cdot 3d}{s} = \frac{\pi \cdot 14^2}{4} \cdot \frac{400 + 2 \cdot 3 \cdot 226}{150} = 1802\ mm^2$$

$$\rho_{l,x} = \rho_{l,y} = \frac{A_x}{b \cdot d} = \frac{1802}{(400 + 2 \cdot 3 \cdot 226) \cdot 226} = 0.0045$$

$$\rho = \frac{A_s}{(6d + a)d}$$

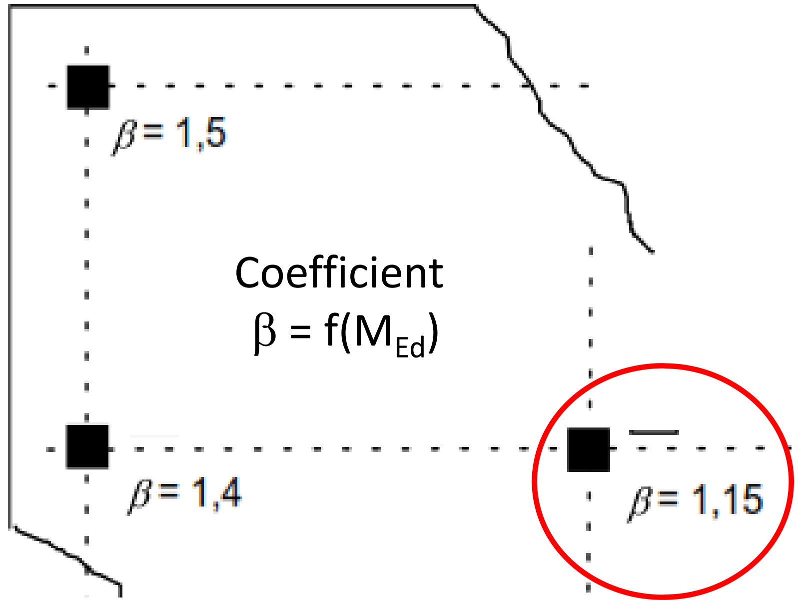


$A_s = A_{s,tensile}$

Checking the shear stress at the column face

$$v_{Ed,u_0} = \beta \frac{V_{Ed}}{u_0 \cdot d} \leq v_{Rd,max} = 0{,}5 \cdot \nu \cdot f_{cd}$$

For structures where the lateral stability does not depend on frame action between the slabs and the columns, and where the adjacent spans do not differ in length by more than 25%, approximate values for β may be used



Column perimeter $u_0 = ?\ mm$

$$\nu = 0{,}6\left(1 - \frac{f_{ck}}{250}\right) = ?$$

$$f_{cd} = \frac{f_{ck}}{\gamma_c} = ?\ MPa$$

→ $v_{Ed,u_0} = ?\ MPa$

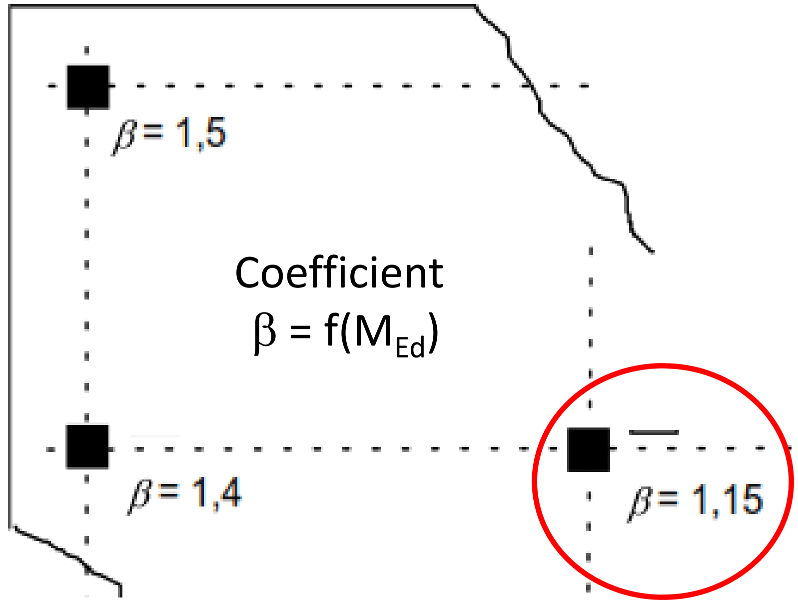
→ $v_{Rd,max} = ?\ MPa$

→ $v_{Ed,u_0}\ <?>\ v_{Rd,max}$

Checking the shear stress at the column face

$$v_{Ed,u_0} = \beta \frac{V_{Ed}}{u_0 \cdot d} \leq v_{Rd,max} = 0,5 \cdot v \cdot f_{cd}$$

For structures where the lateral stability does not depend on frame action between the slabs and the columns, and where the adjacent spans do not differ in length by more than 25%, approximate values for β may be used



Column perimeter $u_0 = 1600\ mm$

$$v = 0,6\left(1 - \frac{f_{ck}}{250}\right) = 0.53$$

$$f_{cd} = \frac{f_{ck}}{\gamma_c} = 20\ MPa$$

→ $v_{Ed,u_0} = 2.70\ MPa$

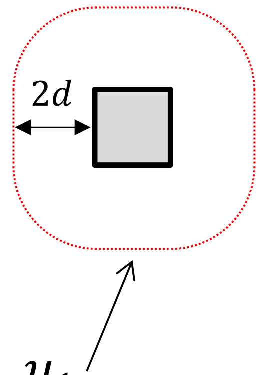
→ $v_{Rd,max} = 5.28\ MPa$

→ $v_{Ed,u_0} < v_{Rd,max}$

design value of the maximum punching shear resistance along the control section considered

Checking the shear force in the basic control perimeter (u_1)

$$v_{Ed,u_1} = \beta \frac{V_{Ed}}{u_1 \cdot d} \leq v_{Rd,c} = C_{Rd,c} k (100 \rho_l f_{ck})^{1/3} \geq v_{min}$$



u_1
basic control perimeter

Basic control perimeter $\qquad u_1 = 2(c_1 + c_2) + 2\pi \cdot 2d = ?\, mm$

$$C_{Rd,c} = 0{,}18/\gamma_c = ?$$

$$k = 1 + \sqrt{\frac{200}{d}} = ? \leq 2$$

$$v_{min} = 0{,}035 k^{3/2} \cdot f_{ck}^{1/2} = ?$$

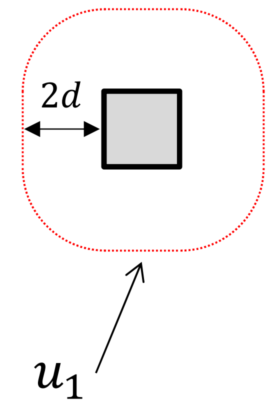
→ $v_{Ed,u_1} = \beta \frac{V_{Ed}}{u_1 \cdot d} = ?\ MPa$

→ $v_{Rd,c} = C_{Rd,c} k (100 \rho_l f_{ck})^{1/3} = ?$

→ $v_{Ed,u_1} <?> v_{Rd,c}$

Checking the shear force in the basic control perimeter (u_1)

$$v_{Ed,u_1} = \beta \frac{V_{Ed}}{u_1 \cdot d} \leq v_{Rd,c} = C_{Rd,c} k (100 \rho_l f_{ck})^{1/3} \geq v_{min}$$



basic control perimeter

Basic control perimeter $\quad u_1 = 2(c_1 + c_2) + 2\pi \cdot 2d = 4440\ mm$

$$C_{Rd,c} = 0{,}18/\gamma_c = 0.12$$

$$k = 1 + \sqrt{\frac{200}{d}} = 1.94 \leq 2$$

$$v_{min} = 0{,}035 k^{3/2} \cdot f_{ck}^{1/2} = 0.52$$

→ $v_{Ed,u_1} = \beta \frac{V_{Ed}}{u_1 \cdot d} = 0.97\ MPa$

→ $v_{Rd,c} = C_{Rd,c} k (100 \rho_l f_{ck})^{1/3} = 0.57$

→ $v_{Ed,u_1} > v_{Rd,c}$

→ transversal reinforcement is needed!

Computation of the control perimeter at which reinforcement is not required (u_{out})

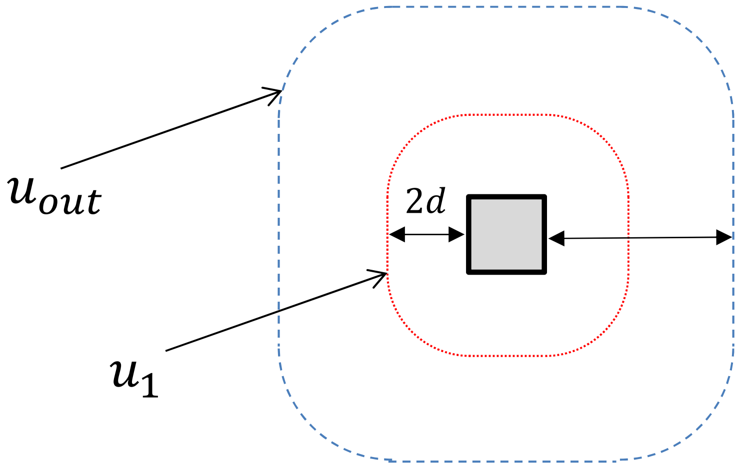
$$u_{out} = \beta \frac{V_{Ed}}{v_{Rd,c} \cdot d} = ?\ mm$$

Distance from the column edge to the control perimeter

$$u_{out} = 2b_c + 2h_c + 4\ quarters = u_0 + 2\pi \cdot xd \quad \rightarrow \quad x = (u_{out} - u_0)/2\pi d$$

$x = ?$

$r_{out} = ?\, d = ?\ mm$



Computation of the control perimeter at which reinforcement is not required (u_{out})

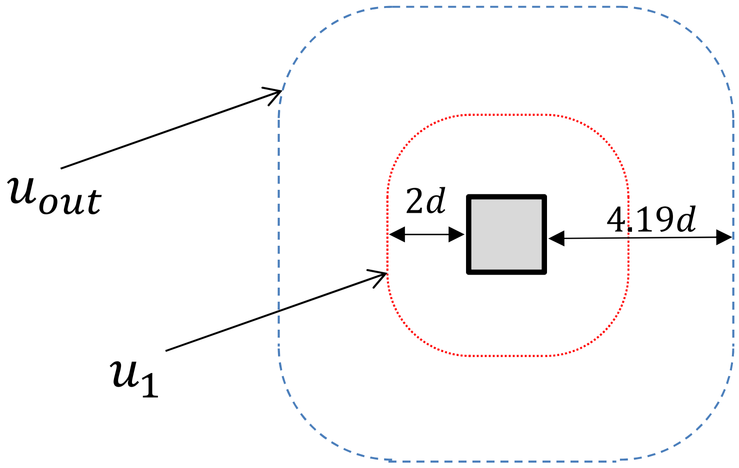
$$u_{out} = \beta \frac{V_{Ed}}{v_{Rd,c} \cdot d} = 7546\,mm$$

Distance from the column edge to the control perimeter

$$u_{out} = 2b_c + 2h_c + 4\,quarters = u_0 + 2\pi \cdot xd \quad \rightarrow \quad x = (u_{out} - u_0)/2\pi d$$

$$x = 4.19$$

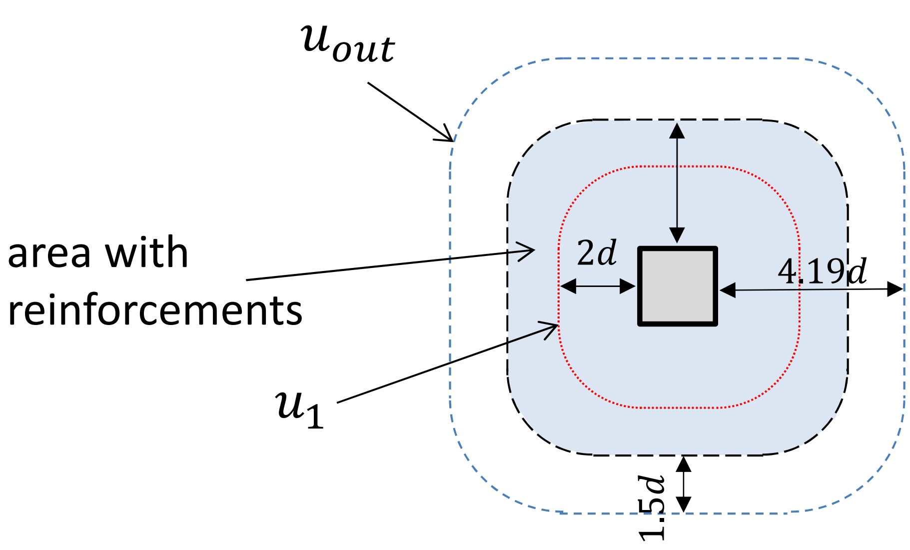
$$r_{out} = 4.19d = 946\,mm$$



Computation of the control perimeter at which reinforcement is not required (u_{out})

The outermost perimeter of shear reinforcement (u_{opr}) should be placed at a distance not greater than *1.5d* within u_{out}

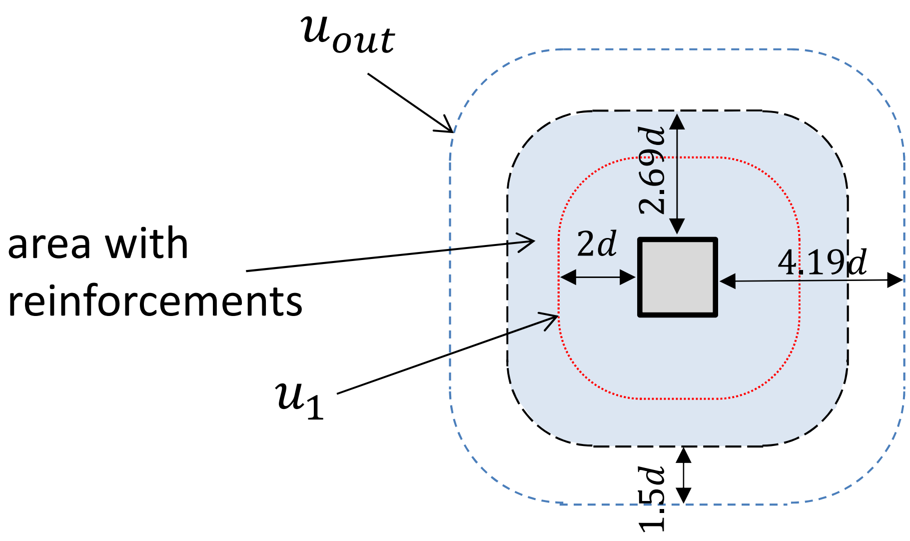
→ $$r_{opr} = r_{out} - 1.5d = ?\,d = ?\ mm$$



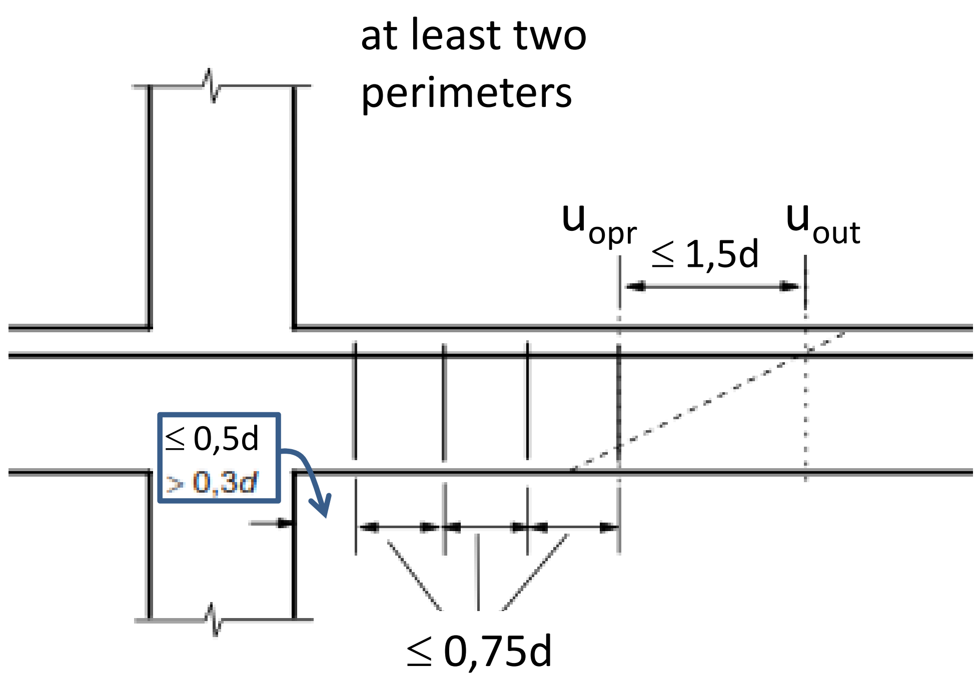
Computation of the control perimeter at which reinforcement is not required (u_{out})

The outermost perimeter of shear reinforcement (u_{opr}) should be placed at a distance not greater than *1.5d* within u_{out}

→ $$r_{opr} = r_{out} - 1.5d = 2.69d = 607\ mm$$



Spacing of shear links in the tangential (s_t) and radial direction (s_r)

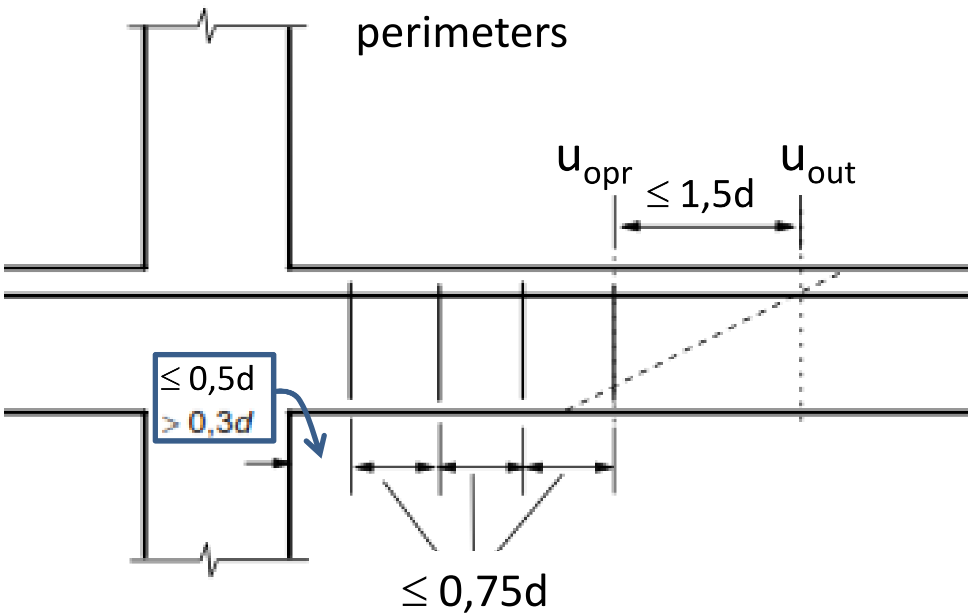


$$s_r \leq 0.75d = ?\ mm \quad \rightarrow \quad s_r = ?\ mm$$

Maximum distance between the face of a support and the nearest shear reinforcement

$$\left.\begin{array}{l} s_{r,max} < 0.5d = ?\ mm \\ s_{r,min} > 0.3d = ?\ mm \end{array}\right\} \rightarrow \quad s_{r,min} = ?\ mm$$

Spacing of shear links in the tangential (s_t) and radial direction (s_r)

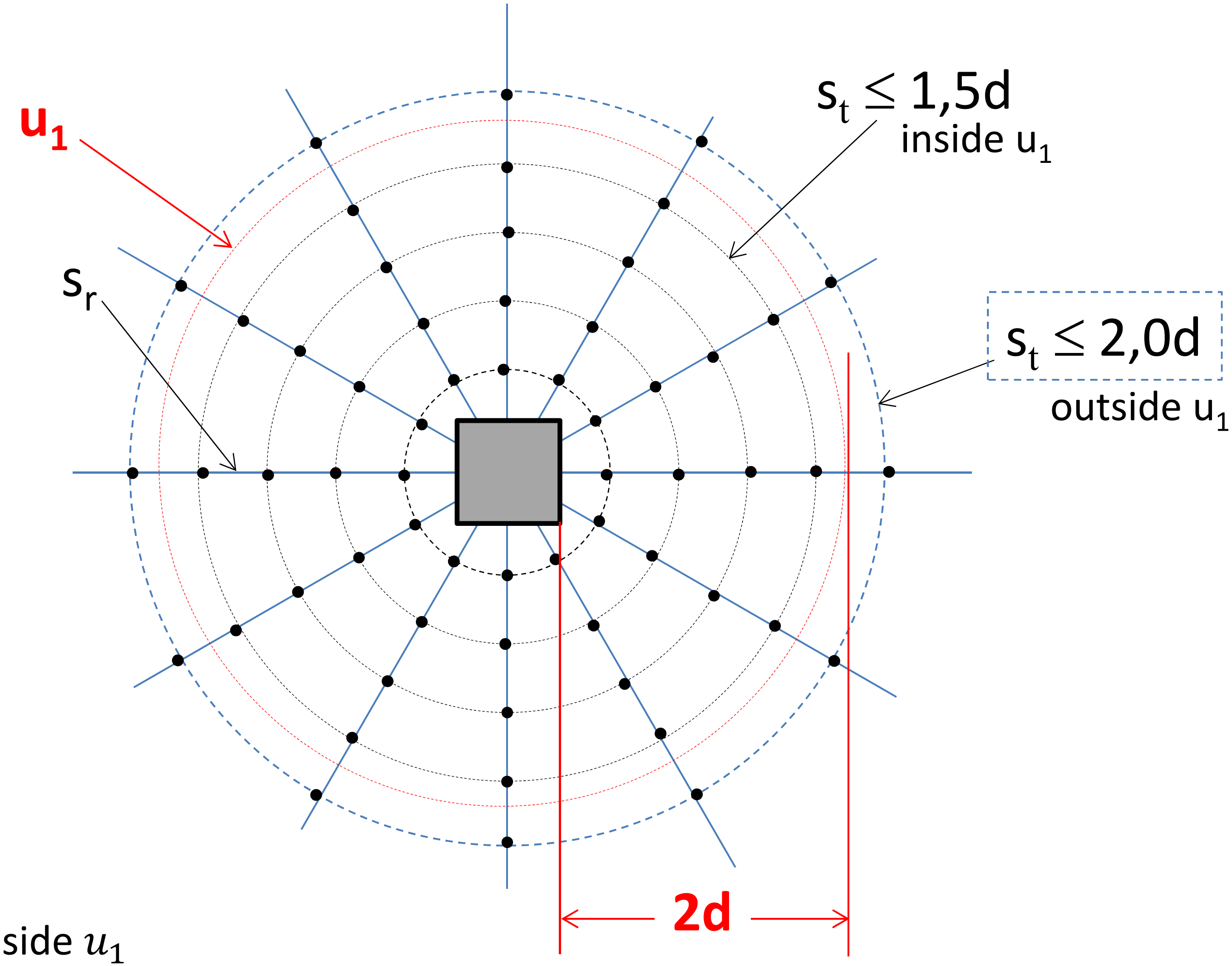


$$s_r \leq 0.75d = 170\ mm \quad \rightarrow \quad s_r = 150\ mm$$

Maximum distance between the face of a support and the nearest shear reinforcement

$$\left.\begin{array}{l} s_{r,max} < 0.5d = 113\ mm \\ s_{r,min} > 0.3d = 67.8mm \end{array}\right\} \rightarrow \quad s_{r,min} = 75\ mm$$

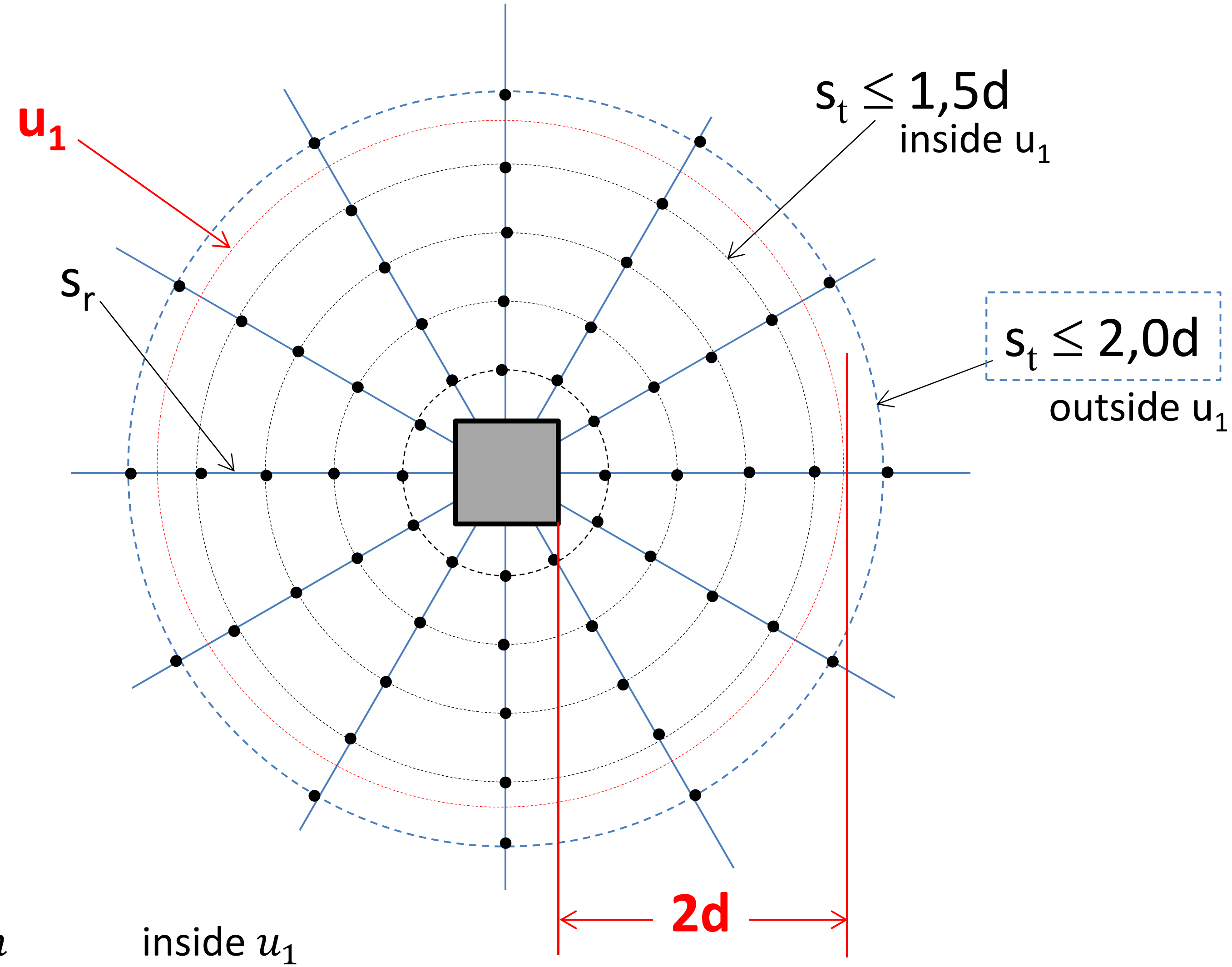
Spacing of shear links in the tangential (s_t) and radial direction (s_r)



$s_t < 1.5d = ?\,mm$ inside u_1

$s_t < 2d = ?\,mm$ outside u_1

Spacing of shear links in the tangential (s_t) and radial direction (s_r)



$s_t < 1.5d = 339\ mm$ inside u_1

$s_t < 2d = 452\ mm$ outside u_1

Spacing of shear links in the tangential (s_t) and radial direction (s_r)

The number of perimeters

$$r_{opr} = r_{out} - 1.5d = 2.69d = 607\ mm$$

1st perimeter distance = ? mm
2nd perimeter distance= = ? mm
3rd perimeter distance= = ? mm
4th perimeter distance= = ? mm
5th perimeter distance= = ? mm

Spacing of shear links in the tangential (s_t) and radial direction (s_r)

The number of perimeters

$$r_{opr} = r_{out} - 1.5d = 2.69d = 607\ mm$$

1st perimeter distance = 75 mm
2nd perimeter distance= (75+150) =225 mm
3rd perimeter distance= (225+150) = 375 mm
4th perimeter distance= (375+150) = 525 mm → $u_{opr} = ?\ mm$
5th perimeter distance= (525+150) = 675 mm → ???

Spacing of shear links in the tangential (s_t) and radial direction (s_r)

The number of perimeters

$$r_{opr} = r_{out} - 1.5d = 2.69d = 607\ mm$$

1st perimeter distance = 75 mm
2nd perimeter distance= (75+150) =225 mm
3rd perimeter distance= (225+150) = 375 mm
4th perimeter distance= (375+150) = 525 mm → $u_{opr} = 4899\ mm$
5th perimeter distance= (525+150) = 675 mm → out of the outermost perimeter of reinforcement

The minimum shear reinforcement area

Required area of one bar in perimeter u_1

$$A_{sw,min} \geq 0.08 \frac{\sqrt{f_{ck}}}{f_{ywk}} \cdot \frac{s_r \cdot s_t}{1.5} = ?\, mm^2 \quad \rightarrow \quad \phi\, ? = ?\, mm^2$$

The minimum shear reinforcement area

Required area of one bar in perimeter u_1

$$A_{sw,min} \geq 0.08 \frac{\sqrt{f_{ck}}}{f_{ywk}} \cdot \frac{s_r \cdot s_t}{1.5} = 29.7\ mm^2 \qquad \rightarrow \qquad \phi\ 8 = 50.3\ mm^2$$

Necessary shear reinforcement area on 1 perimeter

Required area of one bar in perimeter u_1

$$A_{sw,req} = \frac{v_{Ed,u_1} - 0.75 v_{Rd,c}}{1.5 f_{ywd,ef}} u_1 s_r \quad \rightarrow \quad A_{sw,req} = ?\, mm^2$$

$$f_{ywd,ef} = 250 + 0.25d < f_{ywd}$$

$$f_{ywd,ef} = ?\, MPa < 500\, MPa\, ??$$

The necessary number of shear reinforcement per perimeter = ? ? ?

$$\rightarrow \quad ?\ \phi\, ? = ?\, mm^2$$

$$\rightarrow \quad s_t = u_{opr}/(? - 1) = mm \quad < ? > \quad s_{t,max} = 2d = ?\, mm$$

Necessary shear reinforcement area on 1 perimeter

Required area of one bar in perimeter u_1

$$A_{sw,req} = \frac{v_{Ed,u_1} - 0.75 v_{Rd,c}}{1.5 f_{ywd,ef}} u_1 s_r \quad \rightarrow \quad A_{sw,req} = 788\ mm^2$$

$$f_{ywd,ef} = 250 + 0.25d < f_{ywd}$$

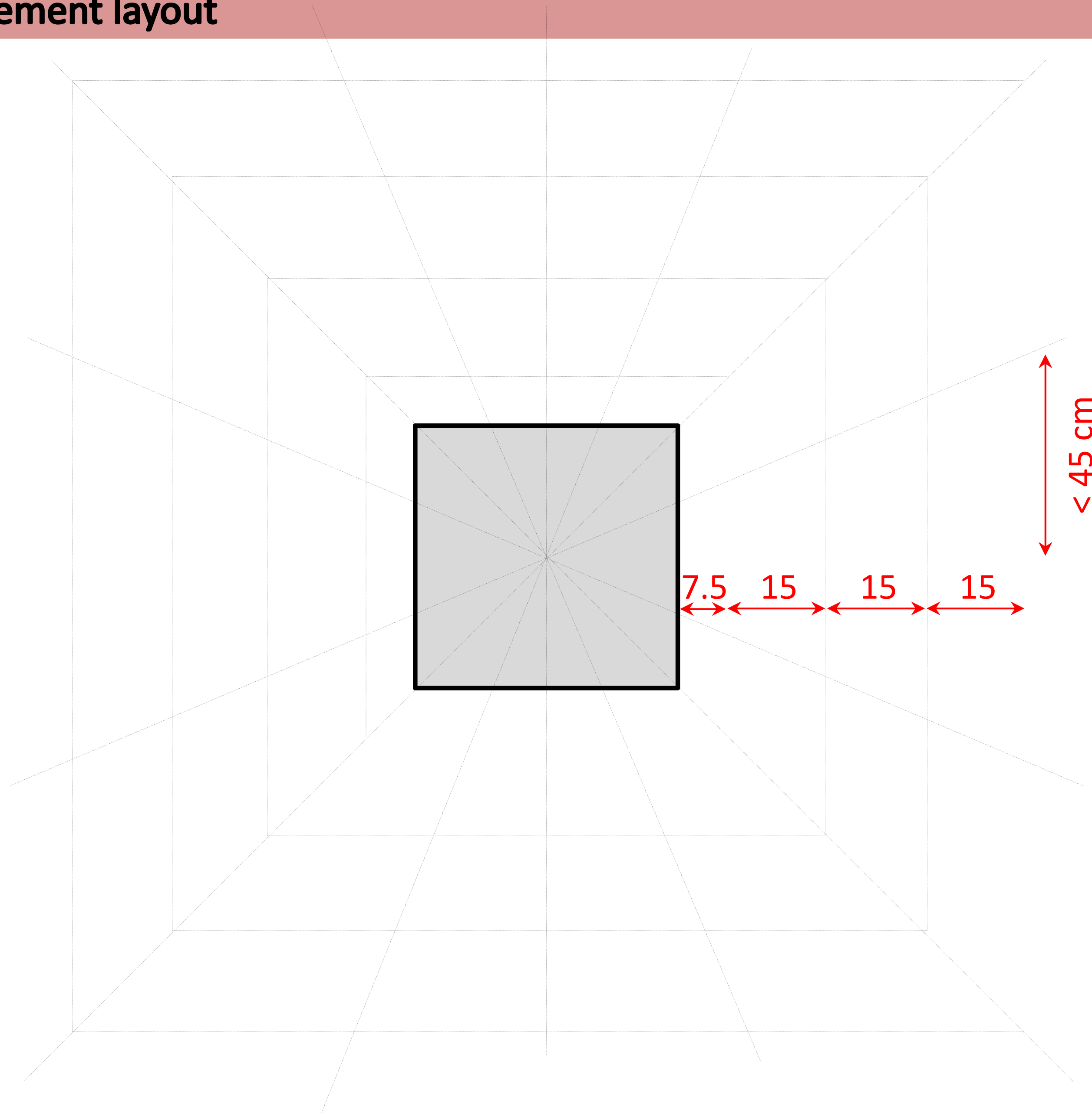
$$f_{ywd,ef} = 307\ MPa < 500\ MPa$$

The necessary number of shear reinforcement per perimeter = $A_{sw,req}/A_{sw,\phi 8}$ = 15.7

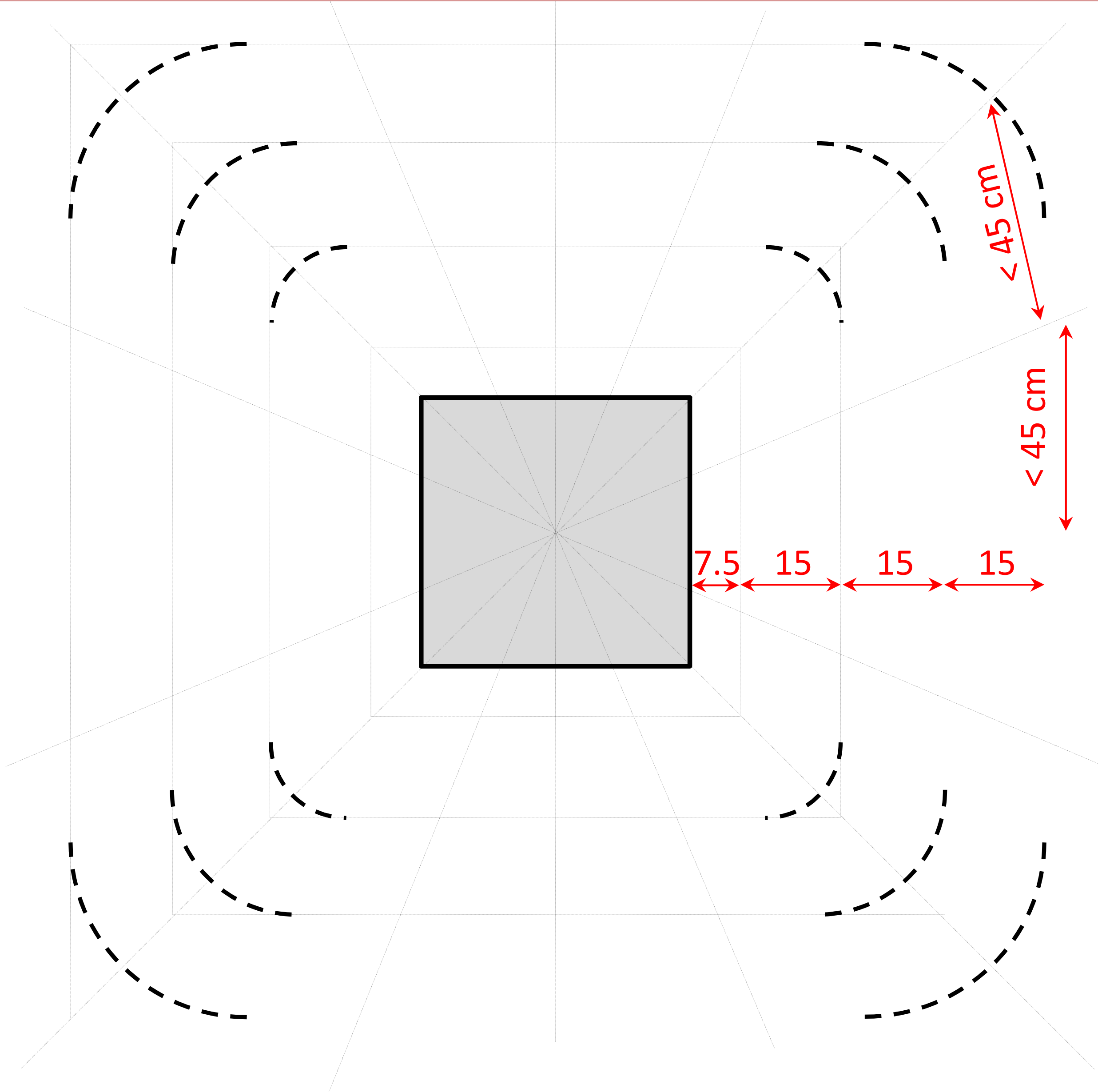
$$\rightarrow \quad 16\ \phi\ 8 = 50.3\ mm^2$$

$$\rightarrow \quad s_t = u_{opr}/(16-1) = 327mm \quad < \quad s_{t,max} = 2d = 452mm$$

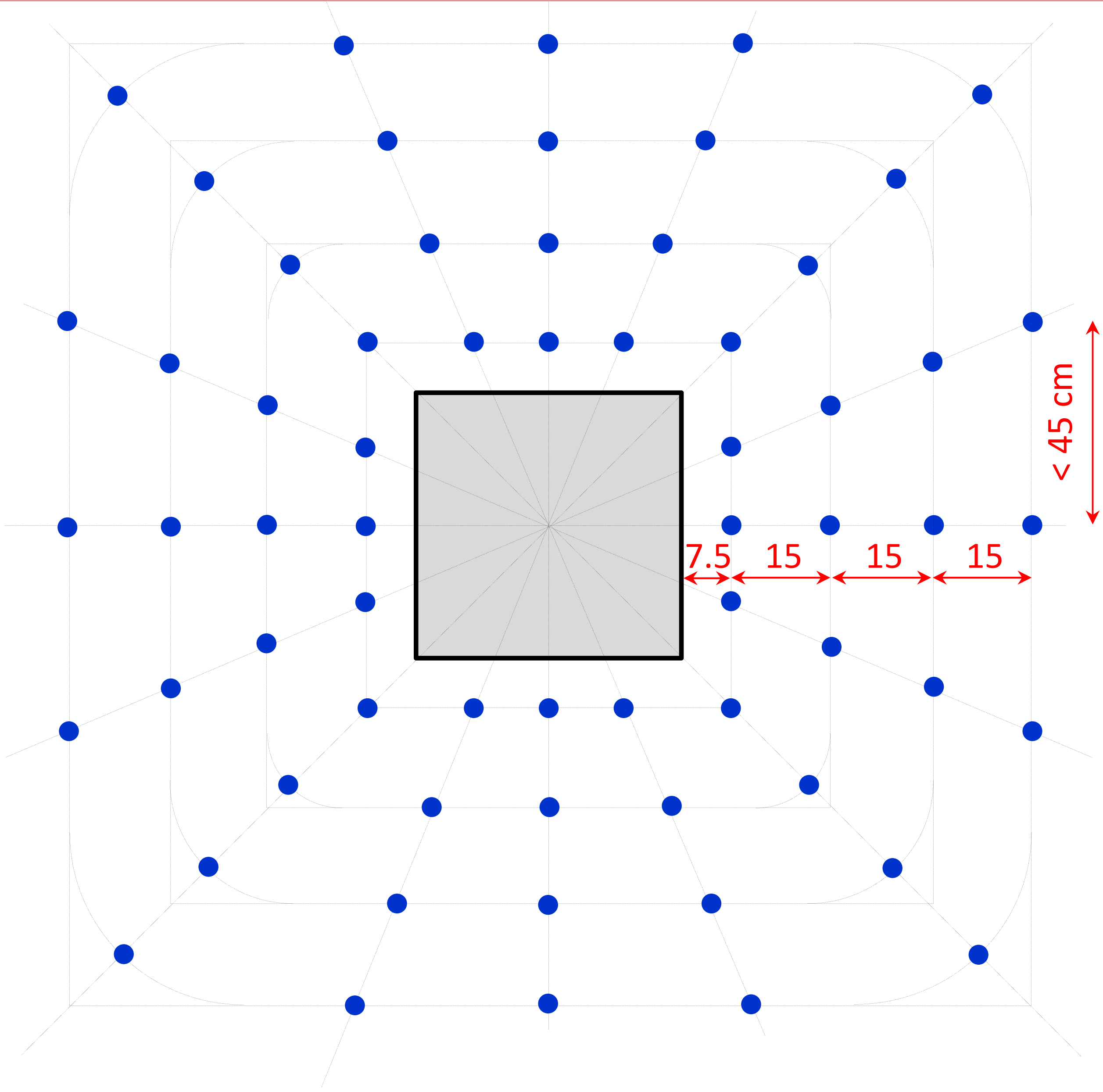
Shear reinforcement layout



Shear reinforcement layout



Shear reinforcement layout



THANK YOU FOR YOUR ATTENTION!

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