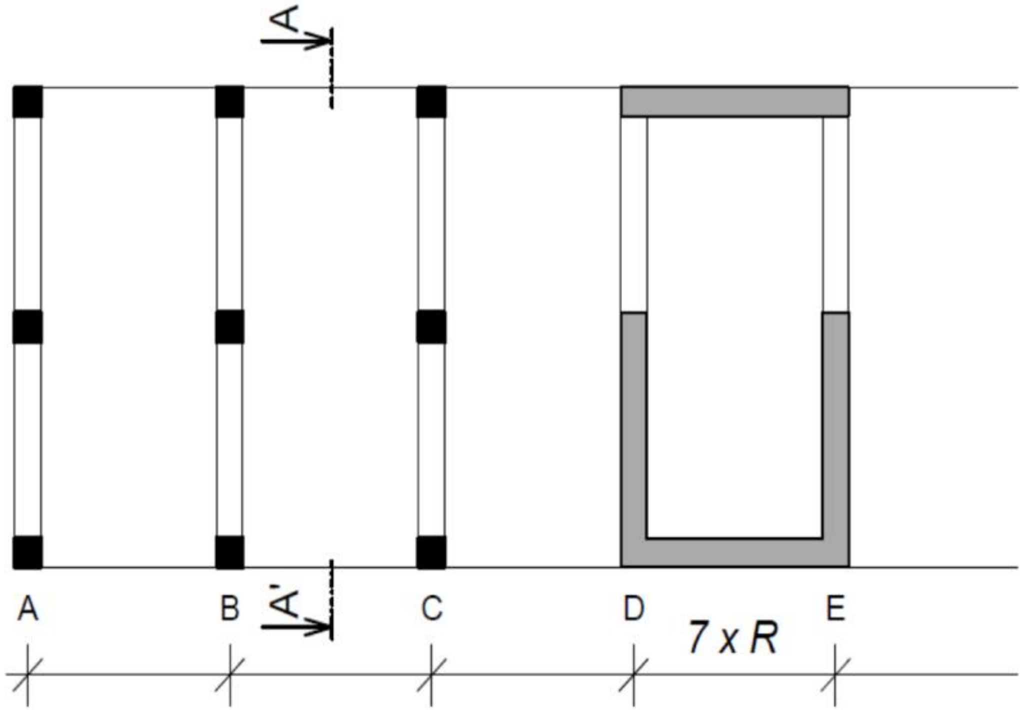
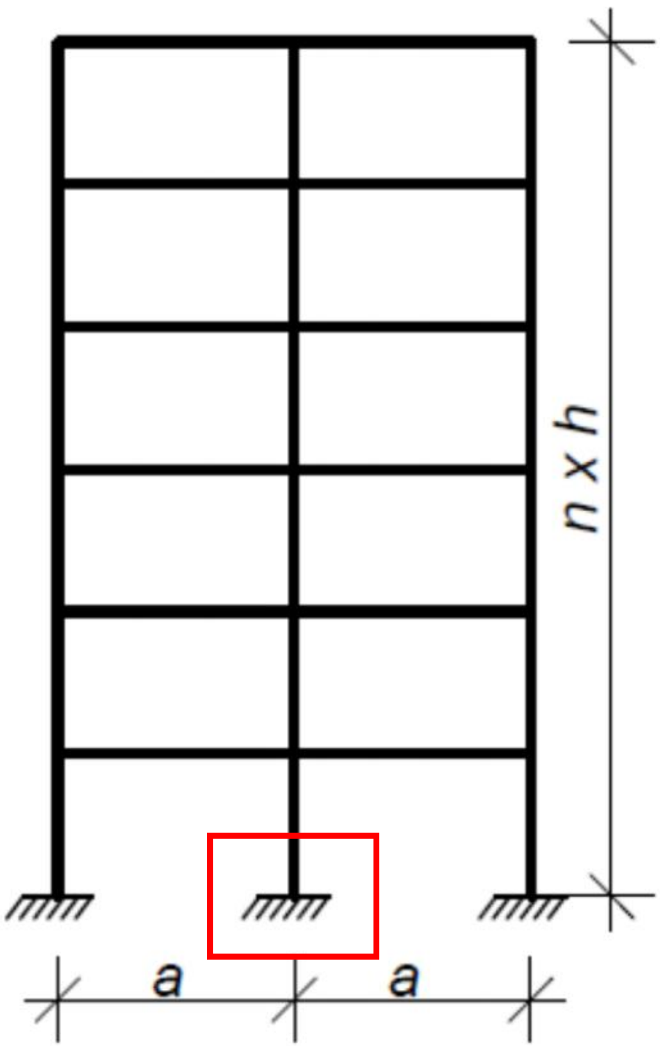
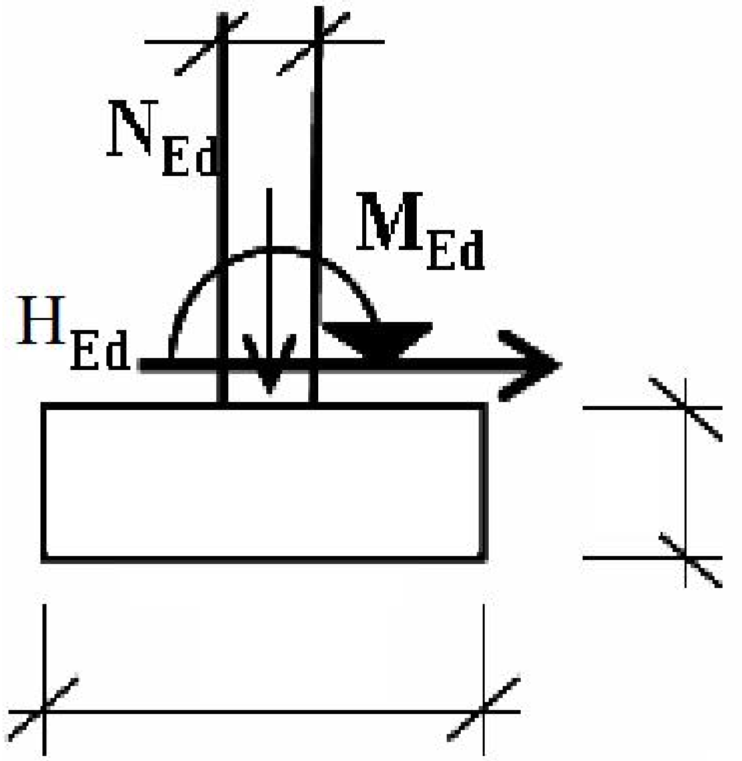
7th task:
Pad footing





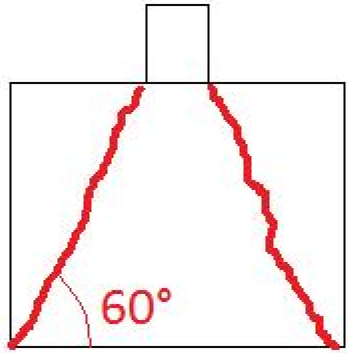
Pad footing

- Design of dimensions
- Design of plain concrete pad footing
- Design of reinforced concrete pad footing
- Drawings (shape and reinforcement of footings)

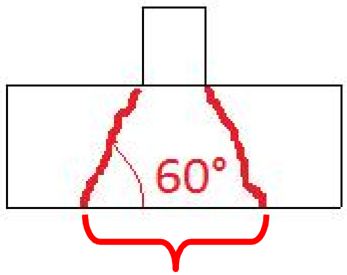


Difference between PC/RC footing

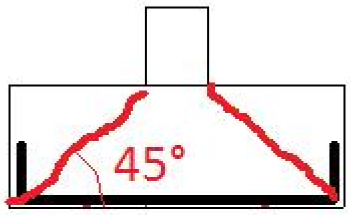
- Difference is in load-bearing angle
- For plain concrete, load-bearing angle is approximately 60°



- For reinforced concrete, the value is 30-45° => footing can be thinner, but you have to use the reinforcement



Without reinforcement, only this part is effective



Reinforcement changes load-bearing angle

Horizontal dimensions

- N_{Ed}, H_{Ed}, M_{Ed} – maximum values in the foot of inner column from 1st task
- Same for plain concrete and reinforced concrete footing
- Self-weight of the footing can be estimated as

$$G_0 = 0.1 N_{\mathrm{Ed}}$$

- Design strength of subsoil (sandy gravel)

$$R_{\mathrm{d}} = 400 \text{ kPa}$$

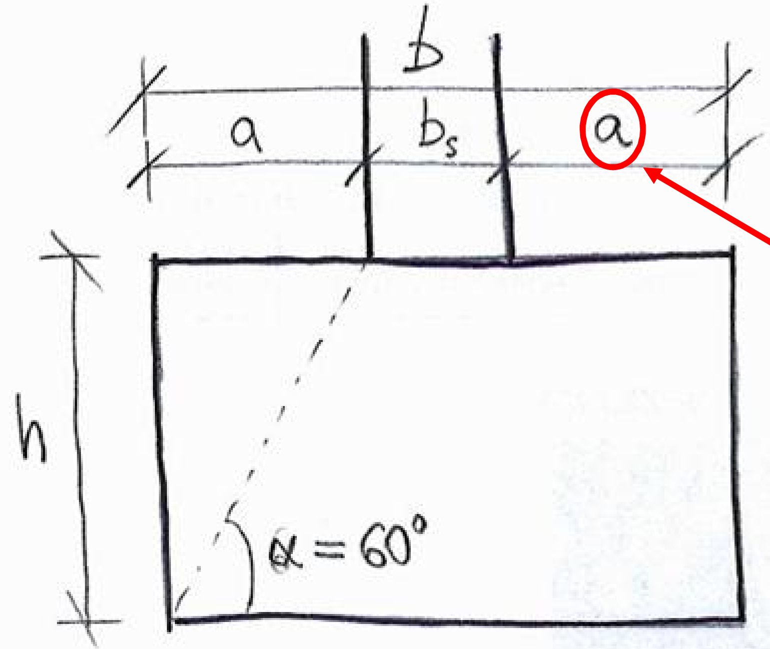
- Eccentricity of loading

Height of the footing

$$e = \frac{M_{\mathrm{Ed}} + H_{\mathrm{Ed}} \cdot h}{N_{\mathrm{Ed}} + G_0}$$

Horizontal dimensions

- The height of the footing is unknown, but we can estimate it from the assumption α = 60 °



$$h = a \cdot \tan\alpha = \left(\frac{b - b_s}{2}\right)\tan\alpha$$

This is not the same a as the span of the frame!!!

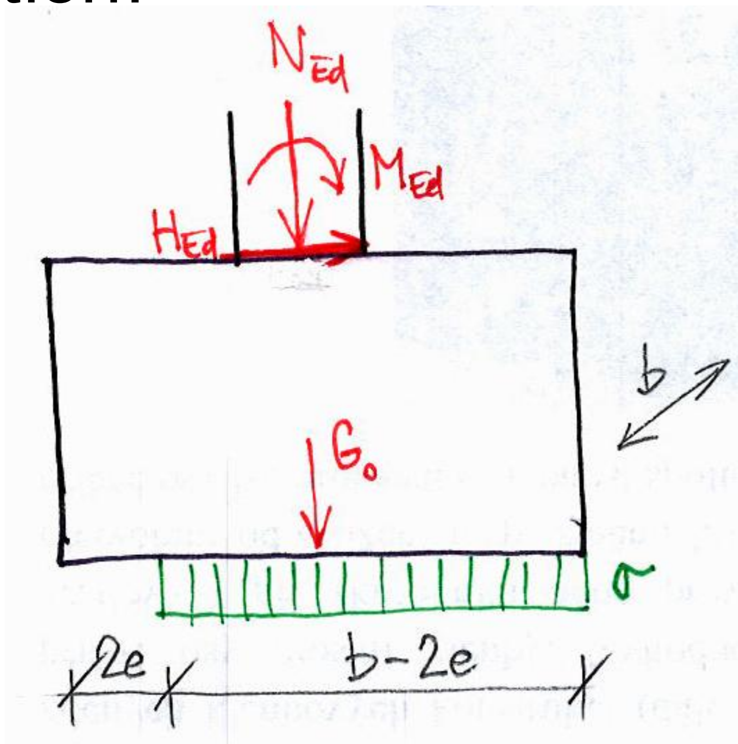
Horizontal dimensions

- Effective area of the footing:

$$\pm = \frac{N_{\mathrm{Ed}} + G_0}{A_{\mathrm{eff}}} \leq R_{\mathrm{d}} \quad \Rightarrow \quad A_{\mathrm{eff}} \geq \frac{N_{\mathrm{Ed}} + G_0}{R_{\mathrm{d}}}$$

- Width of the footing b can be obtained from quadratic equation:

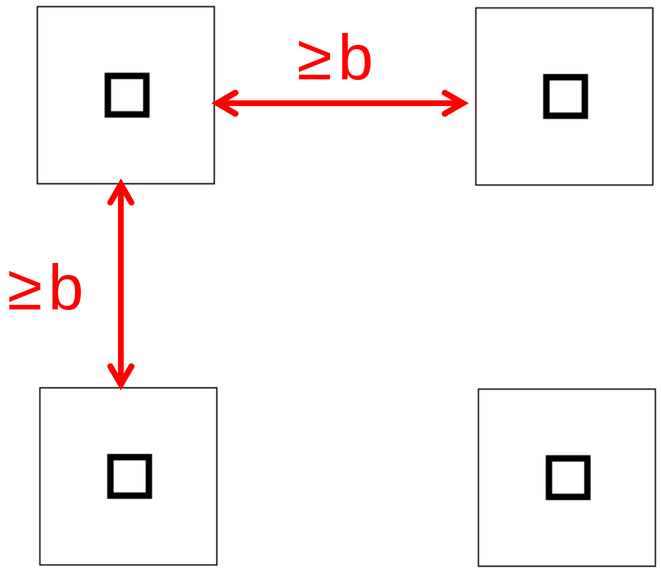
$$A_{\mathrm{eff}} = b \cdot (b - 2e)$$



- Quadratic equation => two roots, only one of them will make physical sense

Horizontal dimensions

- Caluclate <u>real</u> value of b – round to 50 mm
- For further calculations, calculate <u>estimations</u> of h, e and A_{eff}
- Check clear distance of two adjacent pad footings – should be at least b, otherwise strip footings or foundation slab should be used



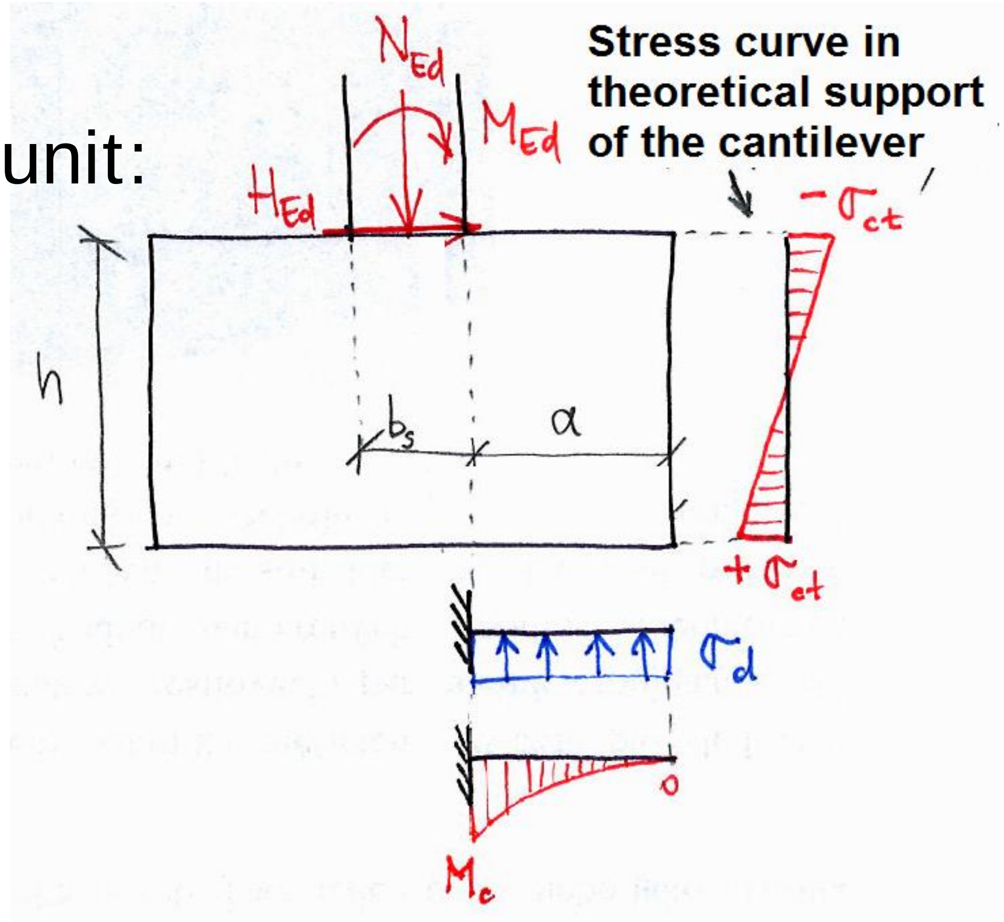
Plain concrete footing

- Footing can be modelled as cantilever of length a
- Design stress that bends the cantilever:

$$\pm_{\mathrm{d}} = \frac{N_{\mathrm{Ed}}}{A_{\mathrm{eff}}}$$

- Bending moment per unit:

$$m_{\mathrm{c}} = \frac{1}{2} \pm_{\mathrm{d}} a^2 \quad [\mathrm{kNm/m}]$$



Plain concrete footing

- Tensile strength of concrete:

Factor expressing the effect of additional shear stresses, 0.8

Characteristic tensile strength of concrete, see table (1st task)

$$f_{\mathrm{ctd}} = \frac{\sim_{\mathrm{ct}}\, f_{\mathrm{ctk,0.05}}}{¥_{\mathrm{c}}}$$

Partial factor, 1.5

- Real height of the footing (round to 50 mm):

$$h \geq \frac{a}{0.85}\sqrt{\frac{3\pm_{\mathrm{d}}}{f_{\mathrm{ctd}}}}$$

Effect of shear

- Calculate real values of e and A_{eff}

Plain concrete footing

- Check of the footing – 2 conditions:
    1. Tensile stress < tensile strength of concrete

$$\pm_{\mathrm{ct}} = \frac{m_c}{W} = \frac{m_c}{\frac{1}{6}bh^2} \leq f_{\mathrm{ctd}}$$

Here we take b = 1 m as we calculated m_c per 1 m

    2. Stress under the footing < strength of subsoil

$$\pm = \frac{N_{\mathrm{Ed}} + G}{A_{\mathrm{eff}}} \leq R_{\mathrm{d}}$$

Self-weight of the footing (NOT the estimated G_0), calculate G from real dimensions of your footing

- If any of the conditions is not checked, the footing should be redesigned (in the homework, just propose the change, do not recalculate)

Reinforced concrete footing

- Choose h = a (load-bearing angle 45°)
- Calculate e, A_{eff} and σ_d (different values than plain concrete footing)
- Reinforced concrete footing can be modelled as cantilever with the length of:

$$l_c = a + 0,15 b_s$$

- Calculate m_c (the same formula as for plain concrete footing, but use l_c instead of a)

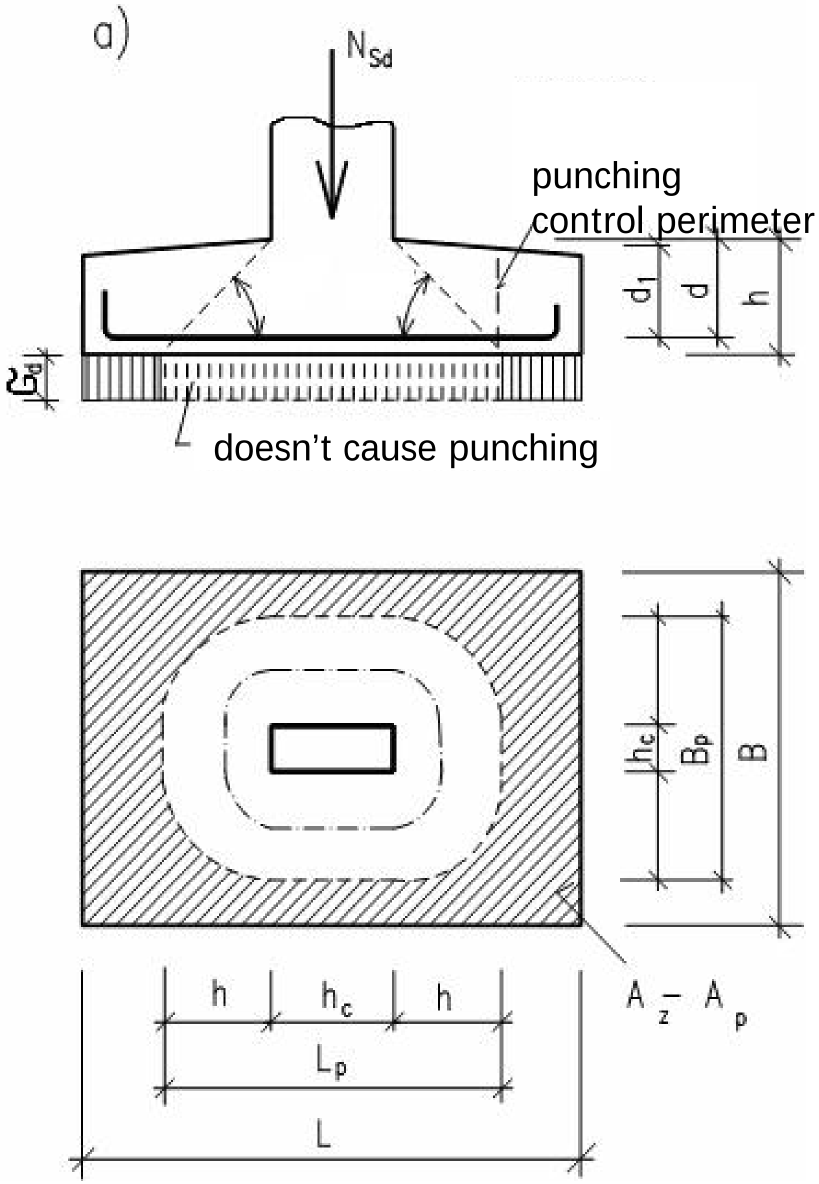
Reinforced concrete footing

- Design and check bending reinforcement – calculation procedure is the same as for slabs or beams
- Value of m_c is in kNm/m => use b = 1 m in calculation of reinforcement !!!
- Use cover depth 50 mm, 14 – 20 mm rebars (use bigger diameters only if necessary)

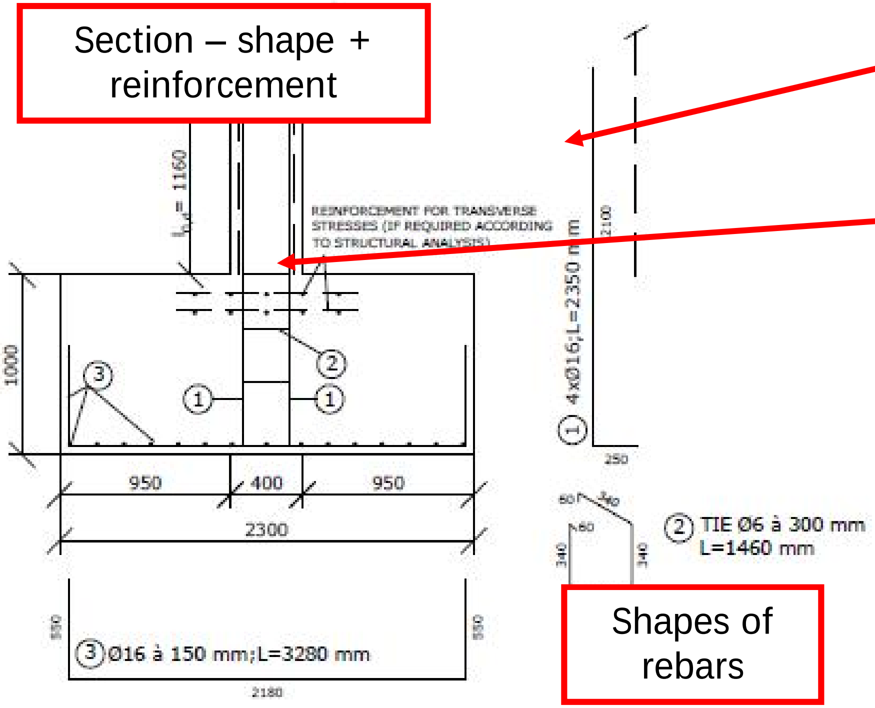
- + Check the stress under the footing (2nd condition for plain concrete footing)

Reinforced concrete footing

- If load-bearing angle is lower (close to 30°), punching reinforcement may be required
- One has to look for critical position of control perimeter $0{,}5d \leq r_u \leq 2d$ where $v_{Rd,i} - v_{Ed,i}$ is minimal (iteration)
- Eventually, punching reinforcement should be designed in this perimeter



Drawings



Starting reinforcement for columns (same as column reinforcement)

Ties – see column reinforcement, middle part

Calculate the amount of reinforcement. Bulk density of steel is 7850 kg/m^3

List of reinforcement

LIST OF REINFORCEMENT					
Item	Rebar	Length	Pieces	Total length of rebars [m]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Ø16
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	18,80
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
3	Ø16	3 280	30		98,40
Total length [m]				4,38	117,20
Unit weight [kg/m]				0,22	1,58
Weight of steel [kg]				0,97	184,94
Total weight of steel				185,91	

Notes

MATERIALS:
CONCRETE C20/25
STEEL B500

COVER DEPTH 50 mm

AXIAL DIMENSIONS OF REBARS

Drawing title

REINFORCEMENT DRAWING –	
[illegible]	1911/12
Checked by: prof. KLOKNER	1:25

TWO DRAWINGS – one for plain concrete and one for reinforced concrete pad footing