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7th TASK: PAD FOOTING

- DATA -

From 1st Task: $M_{Ed} = 4$ KN·m
$V_{Ed} = 1'6$ KN
$N_{Ed} = 2362'5$ KN

$a = 5'6$ m

$b_s = 250$ mm (dimension of my column)

$R_d = 400$ KPa → desing strength of subsoil (sandy gravel)

- HORIZONTAL DIMENSIONS -

The self-weight of the footing can be estimated as:

$G_0 = 0'1 \cdot N_{Ed}$
$G_0 = 0'1 \cdot 2362'5$
$G_0 = 236'25$ KN

Eccentricity of loading: $e = \frac{M_{ed} + V_{ed} \cdot h}{N_{Ed} + G_0}$

$$e = \frac{\overset{KN \cdot m}{4} + 1'6 \cdot h}{2362'5 + 236'25} = \frac{4 + 1'6 \cdot h}{2598'75}$$

1 KPa = 10^{-4} KN/cm²

The effective area of the footing: $A_{eff} \geq \frac{N_{Ed} + G_0}{R_d}$

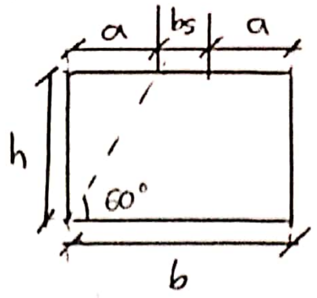
$$A_{eff} = \frac{2362'5 + 236'25 \ [KN]}{400\ e^{-4} \ [KN/cm^2]} = 64968'75 \ cm^2$$

Width of the footing 'b' can be obtained from:

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

Knowing that the height of the footing can be estimate it from the assumption $\alpha = 60°$:

$$h = \left(\frac{b - b_s}{2} \right) tg\,\alpha$$



Therefore, sustituying h & e in the ecuation:

$$64968'75\ (cm^2) = b^2 - 2b \cdot \left(\frac{4 + 1'6 \cdot h}{2598'75} \right)$$

$$64968'75e^{-4}\ (m^2) = b^2 - 2b \cdot \left(\frac{4 + 1'6 \cdot \left(\frac{b - 0'25}{2}\right) \cdot tg60^\circ}{2598'75} \right)$$

Solving this quadratic equation, I obtained:

$b_1 = -2'54$ m ×

$b_2 = 2'55$ m → $b \simeq 3m = 3000mm$

So, the height: $h = \left(\frac{b - bs}{2}\right) \cdot tg\alpha$

$$h = \left(\frac{3e^3 - 250}{2}\right) \cdot tg60 = 2381'57\ mm$$

$h \simeq 2500mm = 2'5\ m$

And the eccentricity:

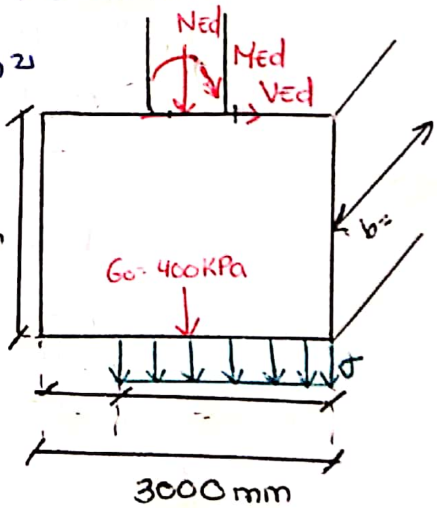
$$e = \frac{4 + 1'6 \cdot 2'5}{2598'75} = 0'003\ m = 3\ mm$$

- $A_{eff} = 8'982 m^2 = 89820\ cm^2$

$$\sigma = \frac{N_{ed} + G_0}{A_{eff}}$$

$$\sigma = \frac{2598'75\ [KN]}{8'982\ [m^2]}$$

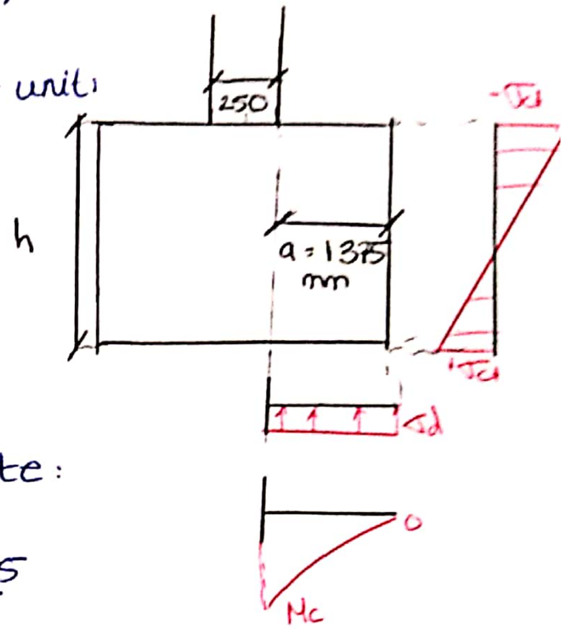
$\sigma = 289\ KN/m^2$



– PLAIN CONCRETE FOOTING –

Desing stress that bends the cantilever.

$$\sigma_d = \frac{N_{Ed}}{A_{eff}} = \frac{2362'5\ (KN)}{8'9824\ (m^2)} = 263\ KN/m^2$$



So, the bending moment per unit:

$$M_c = \frac{1}{2} \cdot \sigma_d \cdot a^2 \ [KN \cdot m/m]$$

$$M_c = \frac{1}{2} \cdot 263 \cdot 1'375^2$$

$$M_c \simeq 249\ KN \cdot m/m$$

Partial factor: $\gamma_c = 1'5$

$\alpha_{ct} = 0'8$

$f_{ctk,0'05}$: 2'25 MPa (from TASK 1 - part 5)

• 1 MPa = 1000 KN/m²

- Tensile strenght of concrete:

$$f_{ctd} = \frac{\alpha_{ct} \cdot f_{ctk,005}}{\gamma_c} = \frac{0'8 \cdot 2'25}{1'5}$$

$$f_{ctd} = 1'2\ MPa$$

Therefore, the <u>real</u> height of the footing:

$$h \geq \frac{a}{0'85} \cdot \sqrt{\frac{3 \cdot \sigma_d}{f_{ctd}}}$$

$$h = \frac{1'375}{0'85} \cdot \sqrt{\frac{3 \cdot 263}{1200}} = 1'31\ m$$

My heigh if I round to 50 m: **h = 1'5 m = 1500 mm**

So the real values of eccentricity and Aeff:

$$e = \frac{4 + 1'6 \cdot 1'5}{2598'75} = 0'00246\ m$$

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

$$A_{eff} = 3 \cdot (3 - 2 \cdot 0'00246) = 8'99\ m^2$$

$$= 89900\ cm^2$$

For the checking of the footing - 2 conditions:

1. Tensile stress < tensile strenght of concrete

where b=1m as we calculated mc per 1m

$$\sigma_{ct} = \frac{m_c}{W} = \frac{m_c}{\frac{1}{6}\cdot b \cdot h^2} \leq f_{ctd}$$

$$\sigma_{ct} = \frac{249}{\frac{1}{6}\cdot 1 \cdot 1'5^2} = 664\ KN = 0'664\ MPa < f_{ctd} = 1'2\ MPa$$ ✓

2. Stress under the footing < strenght of subsoil

G = real self-weight of the footing

$$\sigma = \frac{N_{Ed} + G}{A_{ef}} \leq R_d$$

Considering that the weight of the concrete: 25 KN/m³

$$G = 25\ \frac{KN}{m^3} \cdot 1'5 \cdot 3 \cdot 3 = 337'5\ KN$$

So, $\sigma = \frac{2362'5 + 337'5}{89900} = 0'03\ KN/cm^2$

$R_d = 0'0400 \geq \sigma = 0'03$ ✓

~~So, the footing should be redesigned. I propose to decrease the height of the footing, so the self-weigh will be lower and therefore σ.~~

- REINFORCED CONCRETE FOOTING -

Know, because for reinforced concrete $\alpha = 45°$:

$h = a = 1'375\ m$

→ $e = \frac{.4 + 1'6 \cdot 1'375}{2362'5 + 337'5} = 0'0022\ m$

→ $A_{eff} = 3 \cdot (3' - 2 \cdot 0'0022) = 8'9868\ m^2 = 89968\ cm^2$

→ $\sigma_d = \frac{2362'5}{8'9868} = 262'9\ KN/m^2$

Reinforced concrete footing can be modelled as cantilever with the lenght of:

$$l_c = a + 0'15 \cdot b_s$$
$$l_c = 1'375 + 0'15 \cdot 0'25$$
$$l_c \cong 1'4 m = 1400 mm$$

Therefore: $M_c = \frac{1}{2} \cdot \sigma_d \cdot l_c^2$

$$M_c = \frac{1}{2} \cdot 262'9 \cdot 1'4^2$$
$$M_c \doteq 258 \; KN \cdot m/m$$

→ Rebars 14-20mm

- $d = h - c - \varnothing/2$
$d = 1'375 - 0'05 - 20/2$
$d = 1'315 m$

$f_{yd} = 434'78 MPa$ for B500.

$f_{cd} = 23'3 MPa$ for C35/45

→ $A_{s,rqd} = \frac{M}{0'9 \cdot d \cdot f_{yd}} = \frac{258}{0'9 \cdot 1'315 \cdot 434'78e^3} = 501'4 \; mm^2$

∴ So, with 4 rebars $\varnothing 14$ → $A_{s,prov} = 616 \; mm^2$

DESING: $4 \times \varnothing 14$ ($A_{s,prov} = 616 \; mm^2$) For 1 m

In total: 4x3m=12 rebars

- CHECK OF THE DESING -

$$M_{ed} = A_{s,prov} \cdot f_{yd} \cdot z \geq M_c$$
$$z = d - 0'4 \cdot x$$
$$x = \frac{A_{s,prov} \cdot f_{yd}}{0'8 \cdot b \cdot f_{cd}} = \frac{616e^{-6} \; 434'78}{0'8 \cdot 23'3} = 0'0144 m$$
$$z = 1'315 - 0'4 \cdot 0'0144 = 1'31 \; m$$
$$M_{ed} = 616 \, e^{-6} (m^2) \cdot 1'31 \, (m) \cdot 434'78 \, e^3 \, (KN/m^2)$$
$$M_{ed} = 350'6 KN \cdot m \geq M_c = 258 \; KN \cdot m/m \; ✓$$

- I'm going to calculate the lapping lenghth for the reinforcement of the column: $6\varnothing 20$:
- $\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = \alpha_5 = 1$
- $\alpha_6 = 1'5$
- $\eta_1 = \eta_2 = 1$
- $\sigma_{sd} = f_{yd}$

- LAPPING LENTH -

$$l_{o,d} = \alpha_1 \cdot \alpha_2 \cdot \alpha_3 \cdot \alpha_4 \cdot \alpha_5 \cdot \alpha_6 \cdot l_{b,rqd} \geq l_{o,min}$$
$$l_{b,rqd} = \frac{\varnothing}{4} \cdot \frac{\sigma_{sd}}{f_{bd}} \; ; \; f_{bd} = 2'25 \cdot \eta_1 \cdot \eta_2 \cdot f_{ctd}$$

- $l_{o,min} = max(0'3 \, \alpha_6 \cdot l_{b,rqd}; \; 15\varnothing; \; 200 mm)$

- $f_{bd} = 2'25 \cdot 1'2$ (MPa) = 2'7 MPa

- $l_{b,rqd} = \frac{20}{4} \cdot \frac{434'78}{2'7} = 805$ mm

→ $l_{o,d} = 1'5 \cdot 805 = 1208$ mm

- $l_{o,min} = \max(0'3 \cdot 1'5 \cdot 805 ;\ 15 \cdot 20 ;\ 200)$

  $l_{o,min} = \max(362'25 ;\ 300 ;\ 200)$

  $l_{o,min} = 362'25$ mm $\leq l_{o,d} = 1208$ mm ✓

- SPACING -

For the Aprov for the footing: 9ϕ20

$$S_a = \frac{3000 - 2 \cdot 50 - 2 \cdot 14}{12 - 1} = 220'9 \text{ mm}$$

$S_c = S_a - \phi = 220'9 - 14 = 206'9$ mm

$S_{c,min} = \max(20\text{mm};\ 1'2\phi) = (20\text{ mm};\ 16'8\text{mm}) = 20$mm

$S_{a,max} = \min(2 \cdot h_B;\ 250\text{mm}) = 250$ mm

→ $S_c \geq S_{c,min}$ → : mm ≥ 48mm ✓

→ $S_{a,max} \geq S_a$ → 250mm ≥ 220'9mm ✓

- CHECK STRESS UNDER THE FOOTING -

$$\sigma = \frac{N_{Ed} + G}{A_{eff}} \leq R_d$$

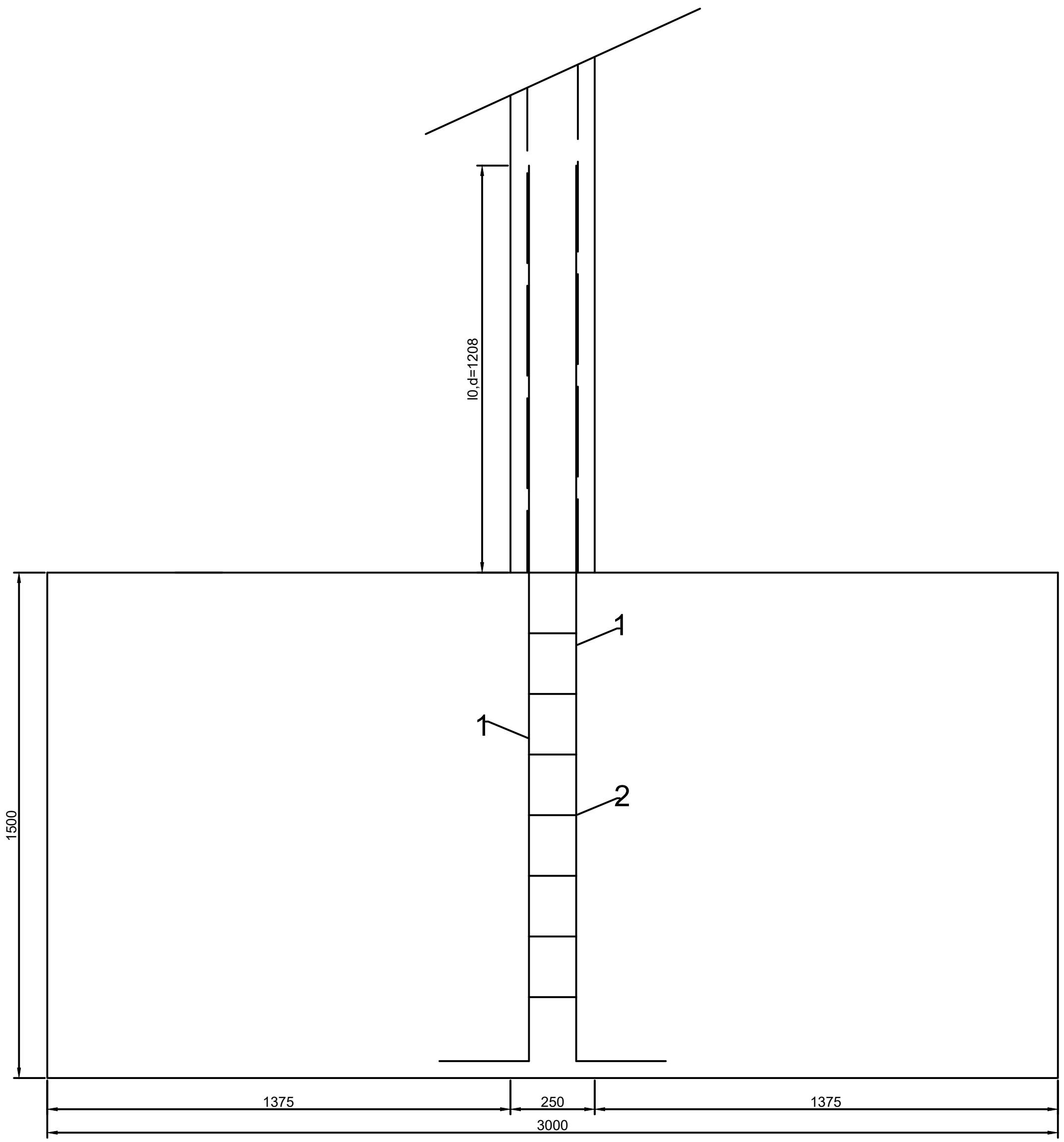
$$\sigma = \frac{2362'5 + 337'5}{89900} = 0'03 \text{ KN/cm}^2 \leq R_d = 0'04 \checkmark$$

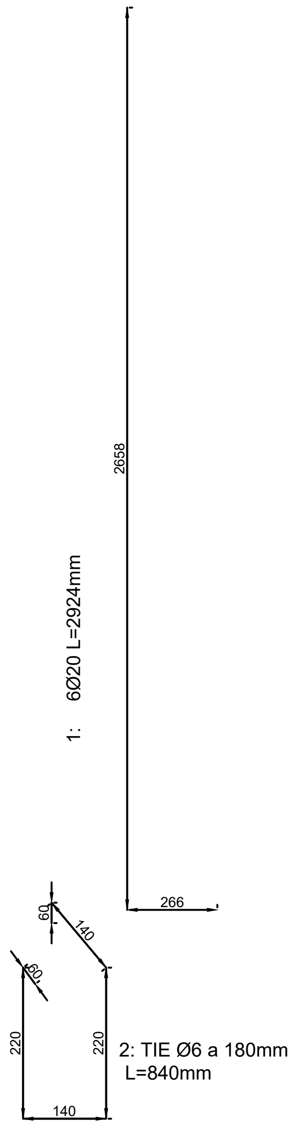
VERA LÓPEZ GARCÍA	
A4	1:1 (mm)

MATERIALS:
CONCRETE C30/35
STEEL B500
COVER DEPTH 50 mm
AXIAL DIMENSIONS OF REBARS

LIST OF REINFORCEMENT				
item	rebar	lenght	pieces	total lenght of rebars
1	Ø20	2924 mm	6	17.5m
2	Ø6	840 mm	8	6.72m

	Ø6	Ø20
Total length [m]	6.72m	17.5m
Unit weight [kg/m]	0.22	2.46
Weight of steel [kg]	1.48	43.05
Total weight of steel	44.53	





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AXIAL DIMENSIONS OF REBARS

LIST OF REINFORCEMENT				
item	rebar	lenght	pieces	total lenght of rebars
1	Ø20	2799 mm	6	16.8m
2	Ø6	840 mm	7	5.88m
3	Ø14	4500 mm	12	54m

	Ø6	Ø20	Ø14
Total length [m]	5.88m	16.8m	54m
Unit weight [kg/m]	0.22	2.46	1.21
Weight of steel [kg]	1.29	41.33	65.34
Total weight of steel	107.96