Design of single footing

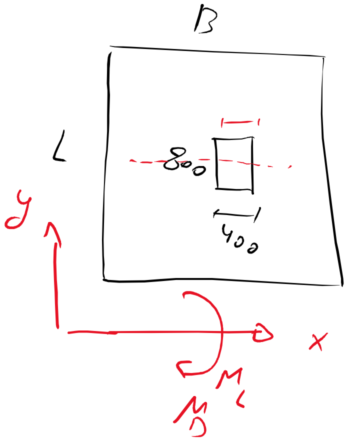
Example: Design single footing to support column 400 x 800 mm, Carrying

P_{DL} = 1700 kw , $q_{all\,soil}$ = 400 kN/m²

P_{LL} = 1300 kw , f'_c = 28 MPa

Footingweight = 10% of total service load

Moment Dead = 255 kw
Moment live : 195 kw] in the strongest column axis



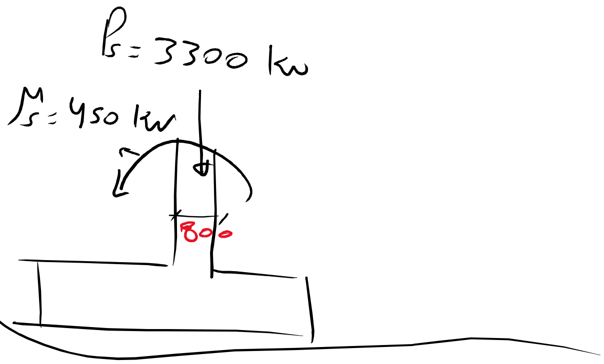
Solution

① P_u

P_s = 1700 + 1300 = 3000 kw

foot weight = 0.1 × 3000 = 300 kw → Dead load.

$P_{D\,total}$ = 1700 + 300 = 2000 kw.



⇒ hint if same example without moment

⇒ Dimension $A = \frac{3300}{400} = 8.25\,m^2$

B − 400 = L − 800

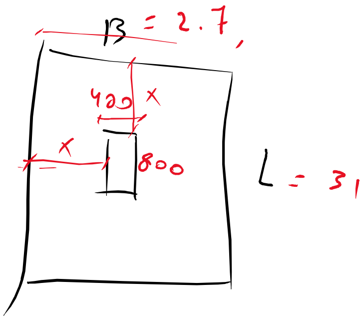
if square column $B = L = \sqrt{8.25} = \underset{2.9m}{2.87m}$

L > 2.9 → Lc − bc = 800 − 400 = 400 → $\frac{400}{2}$ = 200

B < 2.9 →

L = 2.9 + 0.2 = 3.1 → 3.1 − 0.8 = 2.3m ✓

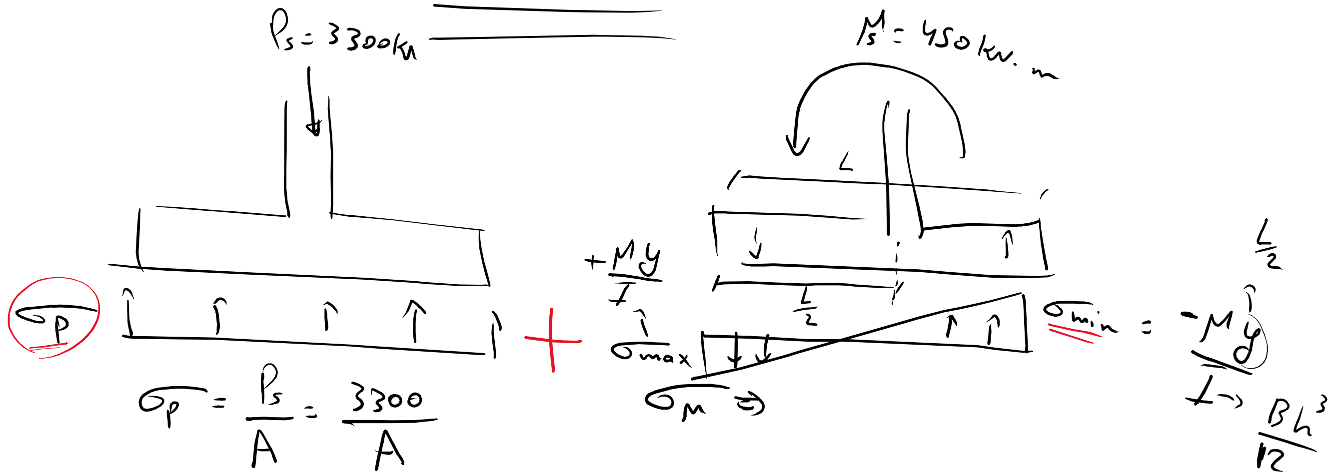
B = 2.9 − 0.2 = 2.7 → 2.7 − 0.4 = 2.3m ✓



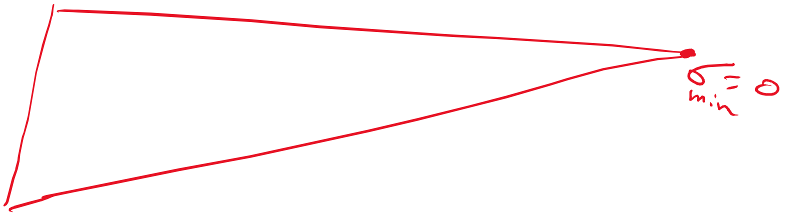
Solution for this example (with moment)

→ stress without moment $\frac{P}{A} = \sigma_{max}$

→ stress with moment $\frac{P}{A} \mp \frac{My}{I}$

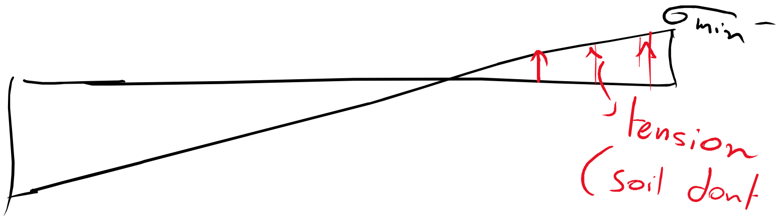


① if $|\sigma_{min}| = |\sigma_p|$



$\sigma_{max} = \sigma_p + \sigma_{M\,max}$

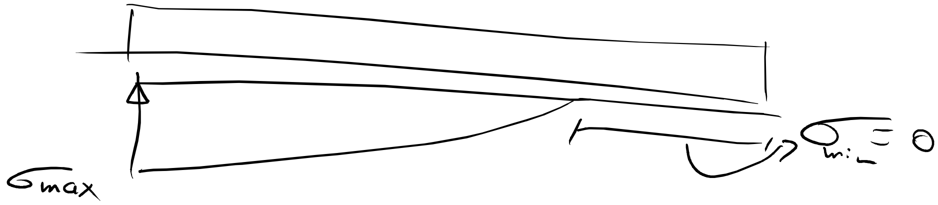
if $|\sigma_{min}| > \sigma_p$



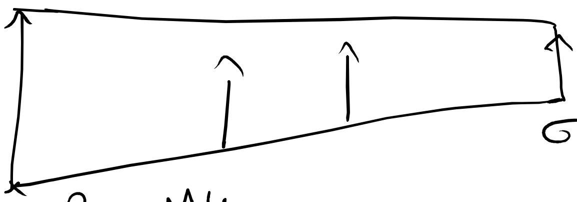
→ negtive → tension

tension (soil dont resist tension)

$\sigma_{max} = \sigma_p + \sigma_{m\,max}$



③ if $|{}_{m}\sigma_{min}| < \sigma_p$



$$\sigma_{min} = \left(\frac{P}{A} - \frac{My}{I}\right) \rightarrow \text{Positive} \rightarrow \text{Compression}$$

$$\sigma_{max} = \frac{P}{A} + \frac{My}{I}$$

$$\sigma_{max} \leq q_{all}$$

$\rightarrow \sigma_{max}$ Case 1 $> \sigma_{max}$ Case 2 $> \sigma_{max}$ Case 3

$$\rightarrow M = \underset{\downarrow}{e} \times P \rightarrow e = \frac{M}{P}$$

الازاحه عن مركز القاعدة

$$\sigma_{max} \leq q_{all}$$

$\sigma_{min} \geq 0$ to avoid tension on Soil

$$\sigma_{max} = \frac{P_s}{A} + \frac{\overset{e \times P_s}{\overset{\uparrow}{M}}\, y}{I}$$

$$\frac{P_s}{A} + \frac{e P_s y}{\frac{B L^3}{12}} \Rightarrow \boxed{\frac{P}{\underset{A}{BL}}\left(1 + \frac{6 \times e}{L}\right)}$$

$$\sigma_{min} = \frac{P_s}{A}\left(1 - \frac{6e}{L}\right)$$

Conti:

$$e = \frac{M}{P} = \frac{450}{3380} = 0.136m$$

$$\Rightarrow \underline{\sigma_{max}} \leq q_{all} = 400$$

$$\frac{3300}{BL}\left(1 + \frac{6 \times 0.136}{L}\right) = 400 \longrightarrow ①$$

$$\Rightarrow \sigma_{min} \geq 0 \Rightarrow \sigma_{min} = 0$$

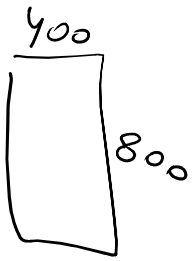
$$\frac{3300}{BL}\left(1 - \frac{6 \times 0.136}{L}\right) \geq 0$$

$$1 - \frac{6 \times 0.136}{L} \geq 0 \Rightarrow \underline{L \geq 0.82m}$$

* assume L from uniform stress and square

$$\Rightarrow L = B = \sqrt{\frac{3300}{400}} = 2.9m$$

→ try value for larger than calculated
then calculate $\underline{B}$



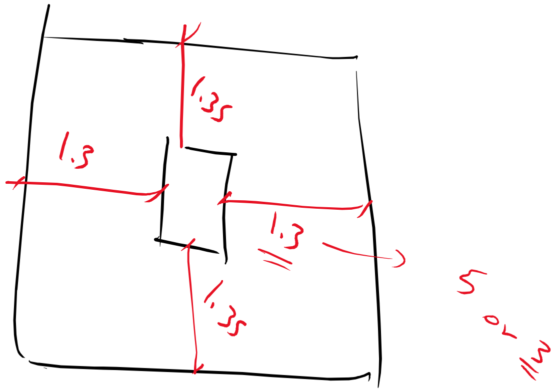
→ assume $\underline{\underline{L = 3.5}}$

$\underline{\underline{B}}$ $\qquad 400 = \frac{3300}{3.5 \times B}\left(1 + \frac{6 \times 0.136}{3.5}\right)$

$B \simeq \cancel{2}.9 \rightarrow B = 3m$

→ $\underline{\underline{\text{arm}}}$ $\qquad L - L_c = B - B_c$

$3.5 - 0.8 = 3 - 0.4$



→ **Thickness**

in single footing punching shear control thickness
if equal arm in x and y

→ $P_u = 1.2 \times 2000 + 1.6 \times 1300 = 4480$ kN

→ $M_u = 1.2 \times 255 + 1.6 \times 195 = 618$ kN

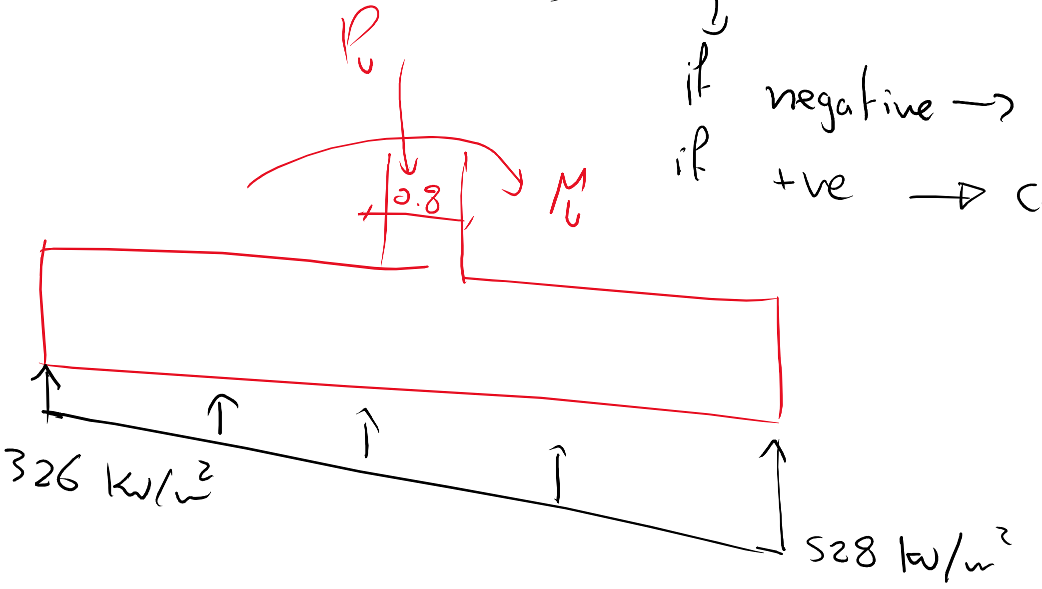
$\sigma_{max}, \sigma_{min} \Rightarrow \underline{\underline{e_u}} = \frac{M_u}{P_u} = \frac{618}{4480} = 0.138m$

$$* \ \sigma_{max} = \frac{4480}{3\times 3.5}\left(1+\frac{6\times 0.138}{3.5}\right) = 528\ kN/m^2$$

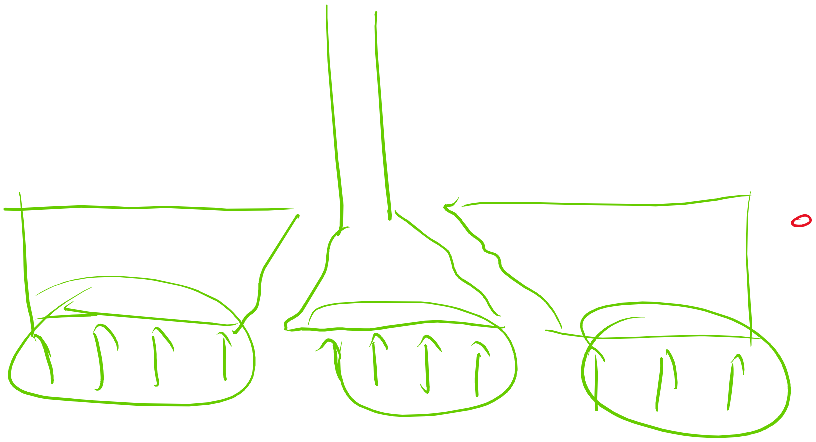
$$* \ \sigma_{min} = \frac{4480}{3\times 3.5}\left(1-\frac{6\times 0.138}{3.5}\right) = \underline{326}\ kN/m^2$$

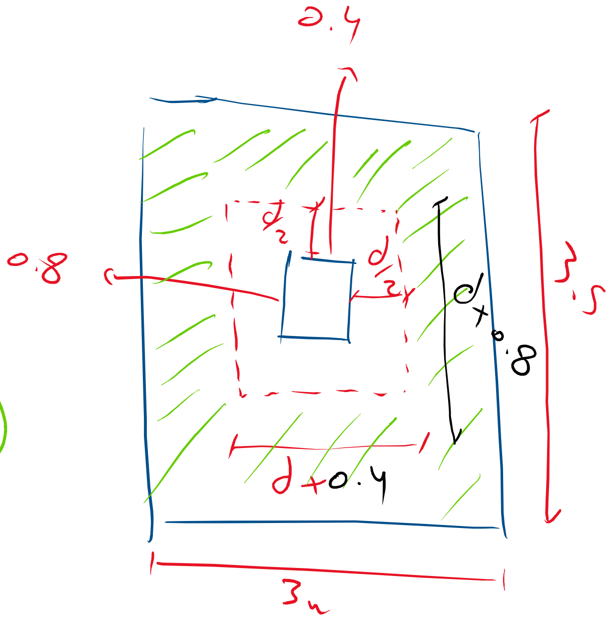
if negative → tension.

if +ve → comprission.



⇒ thickness using punching





* Use σ_{max} to Calculate punching Shear

$$V_u = \sigma_{max} \times Area$$

$$= 528 \times 3 \times 3.5 = 5544 \text{ kN}$$

محيط منطقة ال Punching

$$\phi V_n = 0.75 \times \min \begin{bmatrix} \frac{1}{3} \\ \frac{1}{6}\left(1+\frac{2}{\beta_c}\right) \\ \frac{1}{12}\left(2+\frac{\alpha_s d}{b_o}\right) \end{bmatrix} \times \sqrt{f'_c}\, d \; \underline{\underline{b_o}}$$

in Slabs

$$\beta_c = \frac{L_c}{B_c} = \frac{0.8}{0.4} = 2$$

$$\beta_c \leq 2 \rightarrow \frac{1}{3} \quad / \quad \beta_c > 2 \rightarrow \frac{1}{6}\left(1+\frac{2}{\beta}\right)$$

$$\underline{\underline{b_o}} = 2(800+d) + 2(400+d)$$

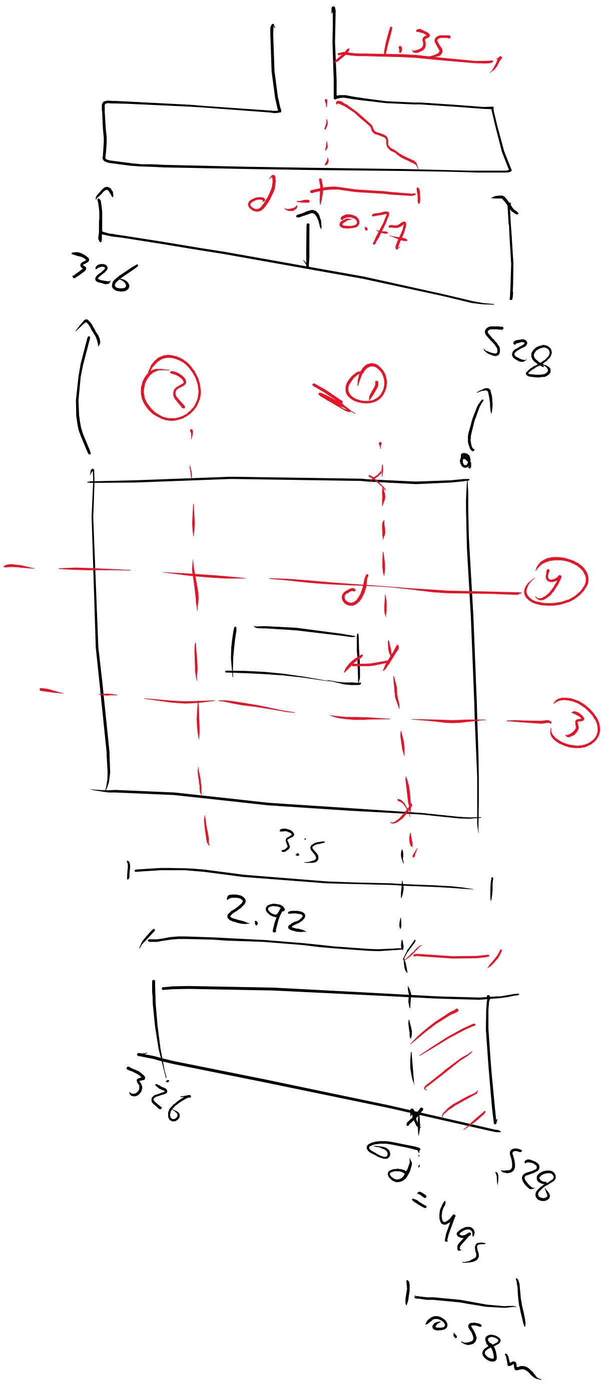
$$= 2400 + 4d$$

$$V_u = \phi V_n$$

$$5544 = 0.75 \times \frac{1}{3} \sqrt{28} \times \frac{d \times (2400+4d)}{1000}$$

$$d \simeq 766\text{mm} \rightarrow h = 770 + 75 = 850 \text{ mm}$$

Check one way Shear



if arms are equal and uniform under

① = ② = ③ = ④

Critical ①

$$\frac{528-326}{3.5-0} = \frac{\sigma_d - 326}{2.92-0}$$

$\sigma_d = 495$ kw/m^2

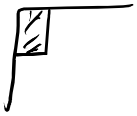
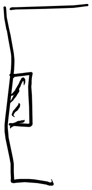
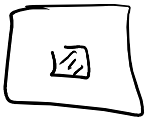
$$V_u = \frac{495+528}{2} \times 3 \times 0.58$$

= 890 kw

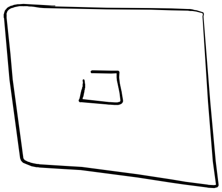
$$\phi V_c = 0.75 \times \frac{1}{6}\sqrt{28} \times \frac{770 \times 3000}{1000} = 1527 \text{ kw} > V_u = 890$$

ok

* thickness of footing based on punching (approximate method)

		Column not subjected to moment (mm)	Column with moment
Corner		$d = 20\sqrt{P_u} \rightarrow$ kN	$d = 20\sqrt{V_u}$
edge		$d = 15\sqrt{P_u}$	$d = 15\sqrt{V_u}$
interior		$d = 10\sqrt{P_u}$	$d = 10\sqrt{V_u}$

→ in this example



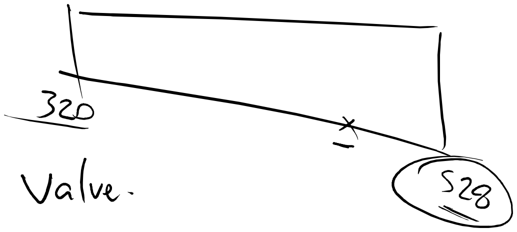
→ interior

$d = 10\sqrt{5544} = 744$ mm

$\underline{V_u}$

* Reinforcement

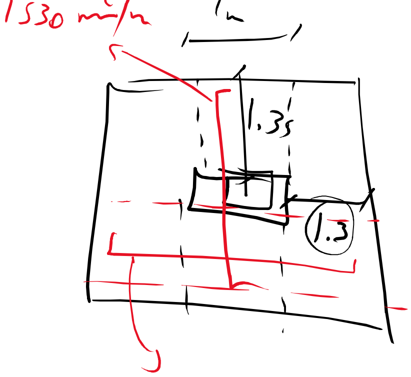
→ assume uniform stress of σ_{max} value.



$$M_{u1} = \frac{\sigma_u L^2}{2}$$

$$= \frac{528 \times 1.35^2}{2}$$

$$= \underline{481} \ kN.m/m$$



$$M_{u2} = \frac{528 \times 1.3^2}{2} = 446 \ kN.m/m$$

$$\rho_{M_{u1}} = 0.00218$$

$$A_s = 0.00218 \times 1000 \times 770 = \underline{1682} \ mm^2/m \ ✓$$

$$A_{s\,min} = 0.0018 \times 1000 \times \overset{h}{850} = 1530 \ mm^2/m$$

$$A_{s\,M_2} = \frac{446}{\underline{481}} \times 1682 = \underline{1560} \ mm^2/m \ ✓$$

long ⇒ 9ϕ16/m

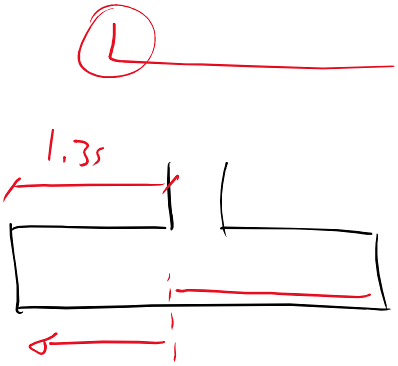
short ⇒ 1560 mm²/m

Development length

$$L_d = 50 \times 16 \times \frac{1682}{1800} = \underline{\underline{748}}\ mm$$

1800

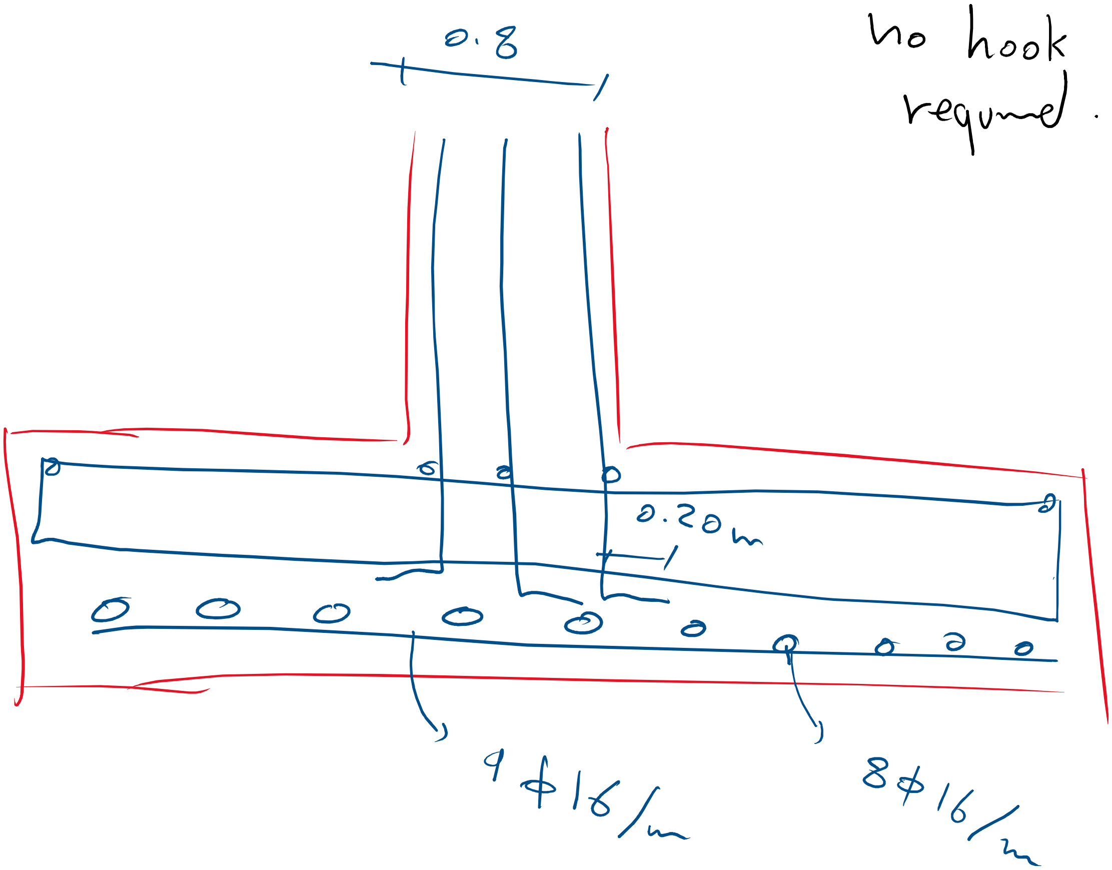
As of 9ϕ16

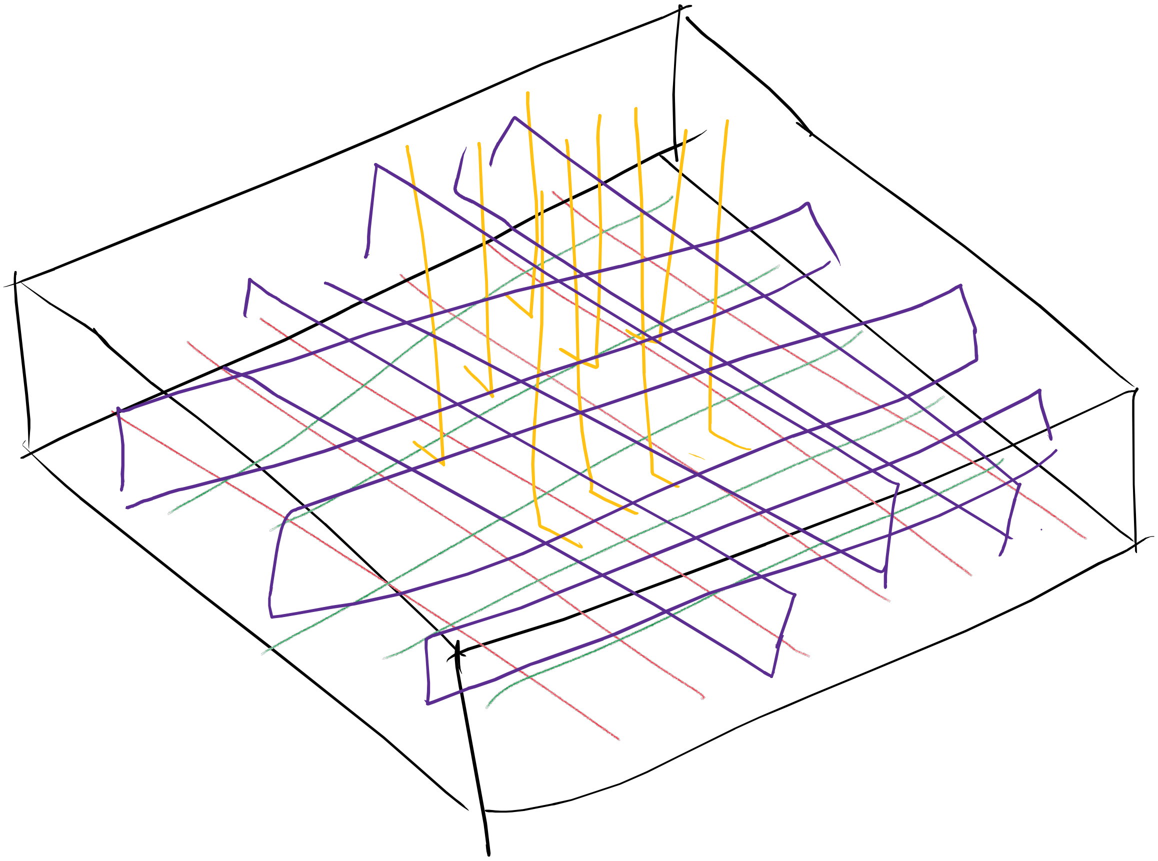


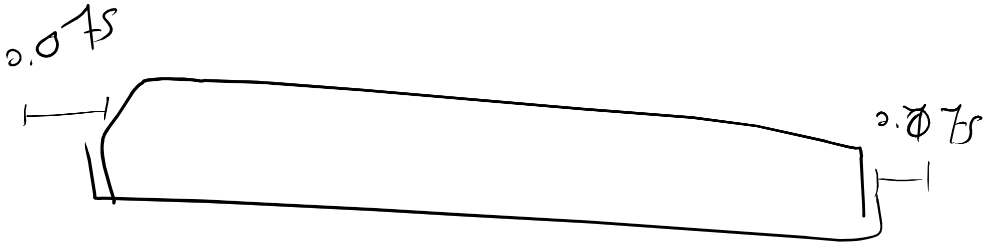
Available length $= \underset{\text{arm}}{1.35} - 0.075$

$= 1.275 > L_d = 748\ mm$ ok

no hook required.







$B_p = 3m$

bar length = B + 2x Cover

3 - 2x0.075