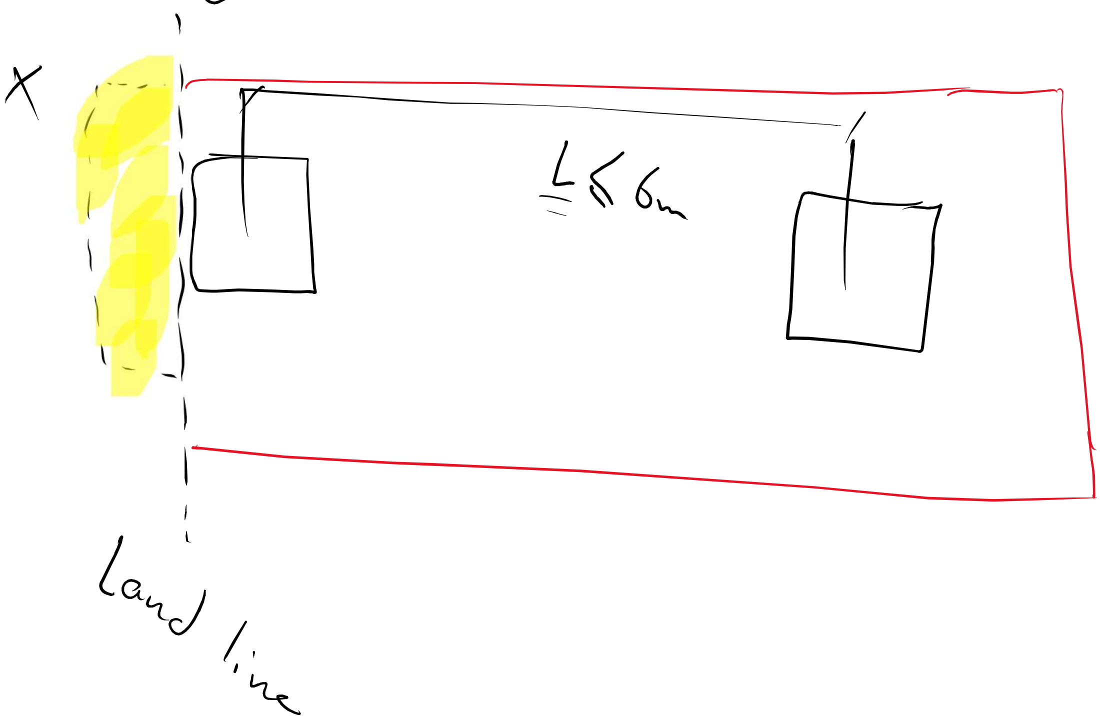
Combined footing

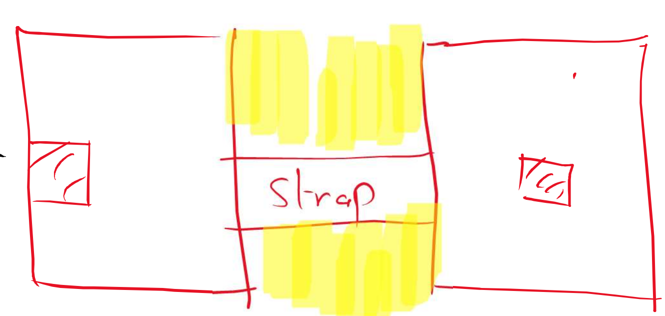
① 

Soil → Clay → < 100 kN/m²

② 

Combined footing L < 6m

Strap footing. L > 6m



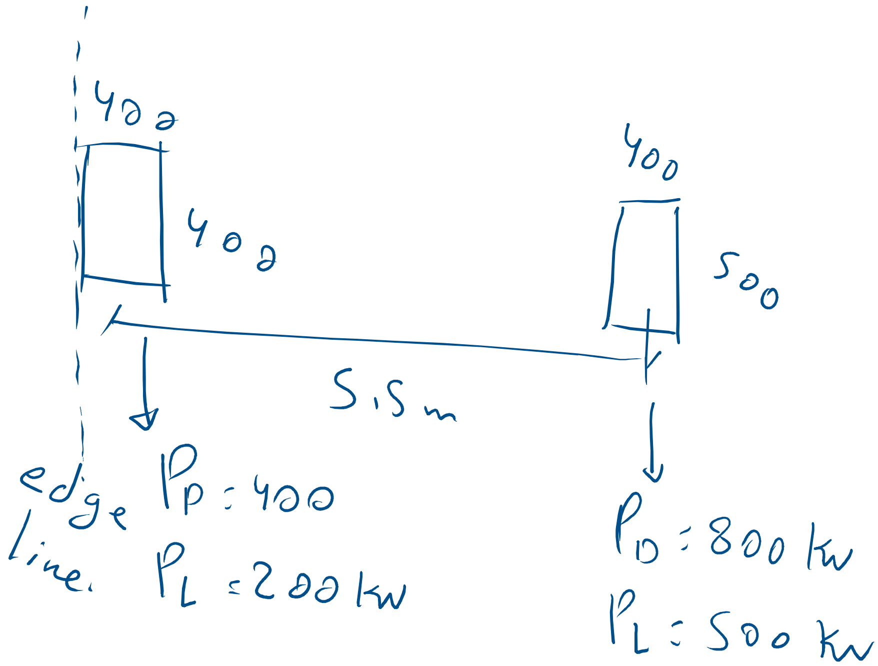
Example 3

Design combined footing to carry the load on the columns shown.

$f'_c = 21$ MPa.

$f_y = 420$ MPa.

$q_{all} = 180$ kN/m^2



if Isolated footing Considered

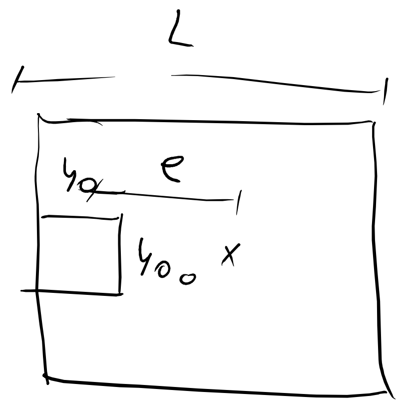
$\Rightarrow \frac{L}{2} - e = 0.2$

$e = \frac{L}{2} - 0.2$

to avoid tension (+) $1 - \frac{6e}{L}$

$L \geq 6e$

$L \leq 0.6$ m.

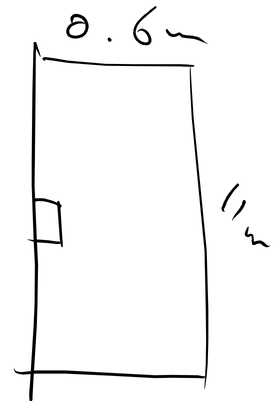


$P_p = 400$

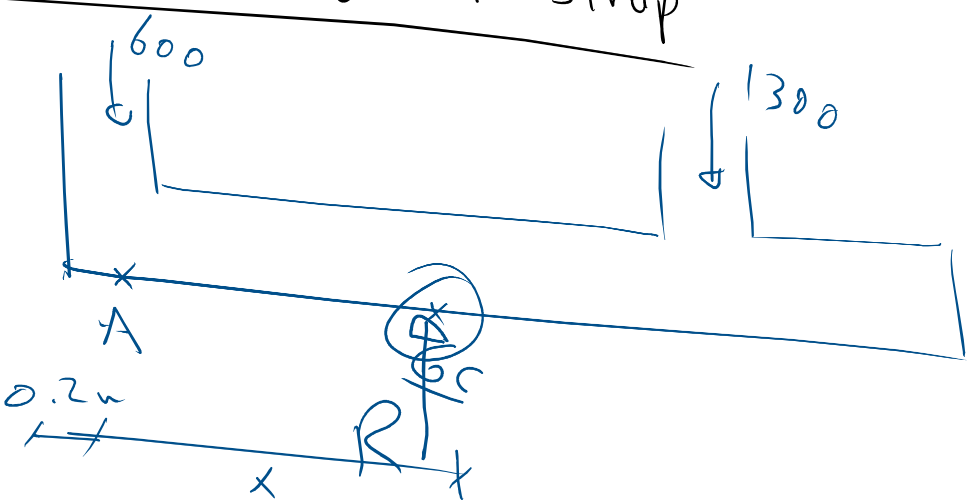
$P_L = 200$

$\rightarrow B \rightarrow 180 = \left(\frac{600}{B \times 0.6}\right)\left(1 + 6 \times \frac{0.6}{2} - 0.2\right) = 180$ (P_s)

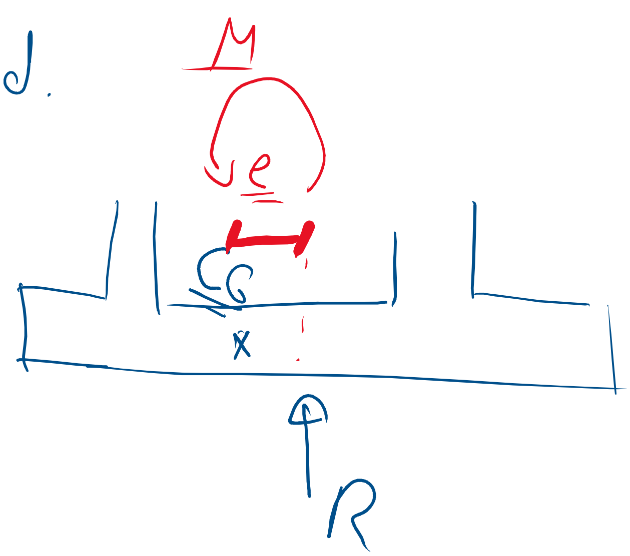
B = 11m



→ So use Combined or Strap

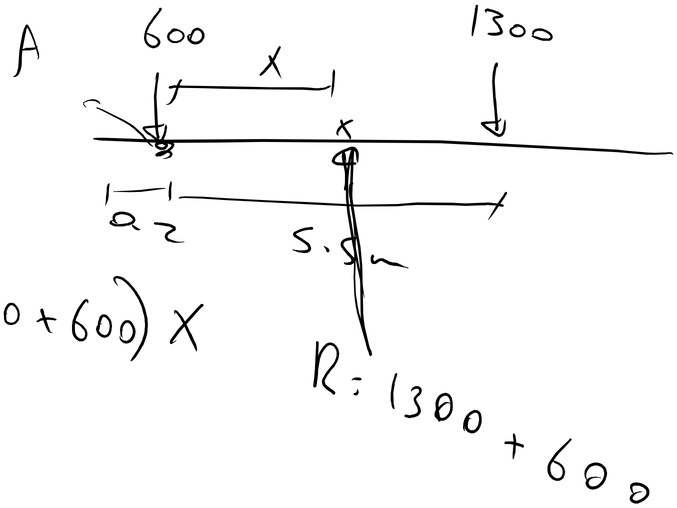


to create uniform Stress under footing.
Calculate dim to make center of footing equal center of load.



$$\Sigma M_A = 0$$

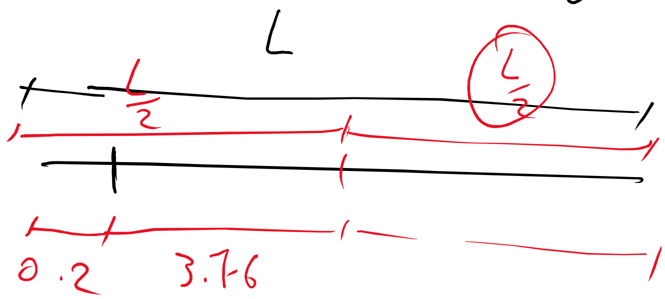
$$= 1300 \times 5.5 - (1300 + 600) X$$



$$\rightarrow X \simeq 3.76 m$$

$$\rightarrow L = 2(3.76 + 0.2)$$

$$= 7.93 m$$



assume $L = 8 m$ → uniform stress

$$\rightarrow \sigma = \frac{P}{A} = \frac{1300 + 600}{B \times 8m} = 180$$

σ ↓ q_{all}

$$B = 1.4 m$$

Notes

Change L → non uniform Stress.

Change B → Change in Stress Value.

Thickness

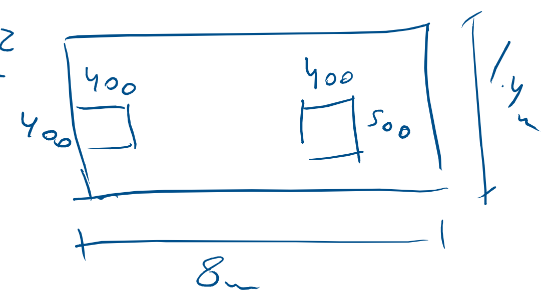
① → punching

→ one way shear

→ $P_{u_1} = 400 \times 1.2 + 200 \times 1.6 = 800\ kN$

→ $P_{u_2} = 800 \times 1.2 + 500 \times 1.6 = 1760\ kN$

→ $\sigma_u = \dfrac{800 + 1760}{1.4 \cdot 8m} = 228.6\ kN/m^2$

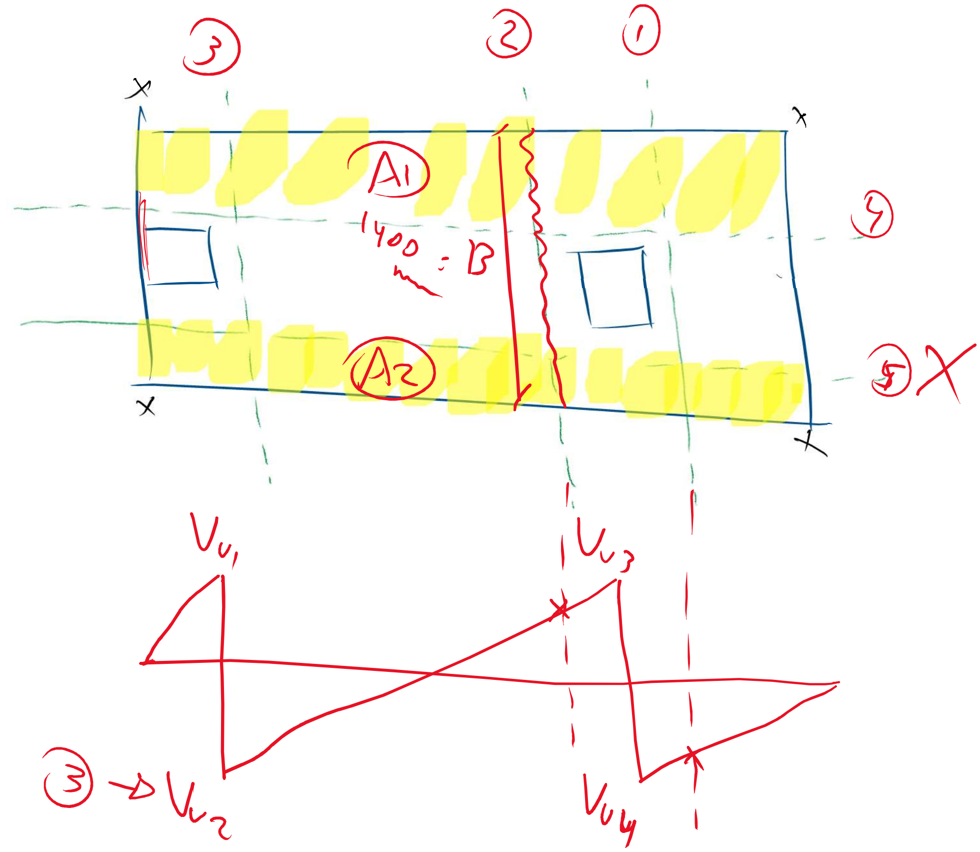


→ One Way Shear

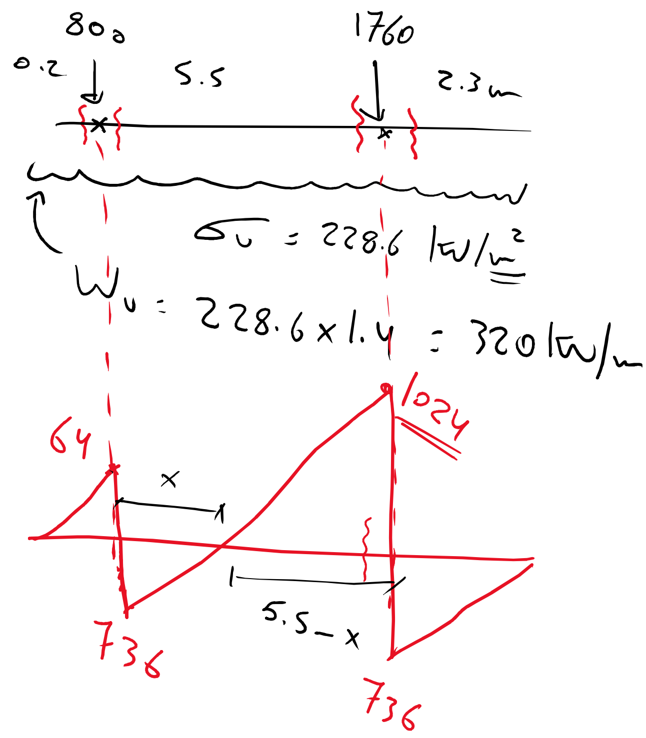
↑ V_u

↓ ϕV_c

④ = ⑤



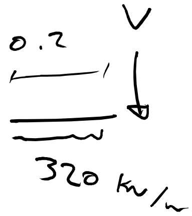
SFD



$\sigma_u = 228.6 \text{ kN/m}^2$

$W_u = 228.6 \times 1.4 = 320 \text{ kN/m}$

①

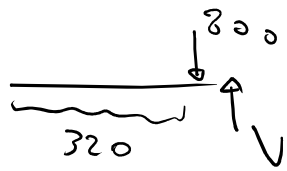


$\Sigma F_z = 0$

$320 \times 0.2 = V$

$V = 64 \text{ kN}$

②

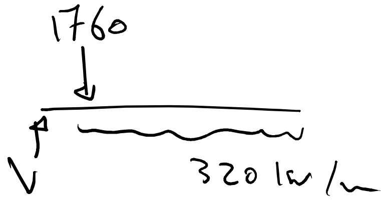


$\Sigma F_z = 0$

$320 \times 0.2 - 800 + V = 0$

$V = 736 \text{ kN}$

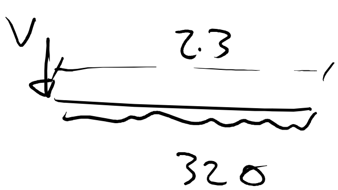
③



$\Sigma F_z = 0 \rightarrow 320 \times 2.3 + V - 1760$

$= 1024$

④

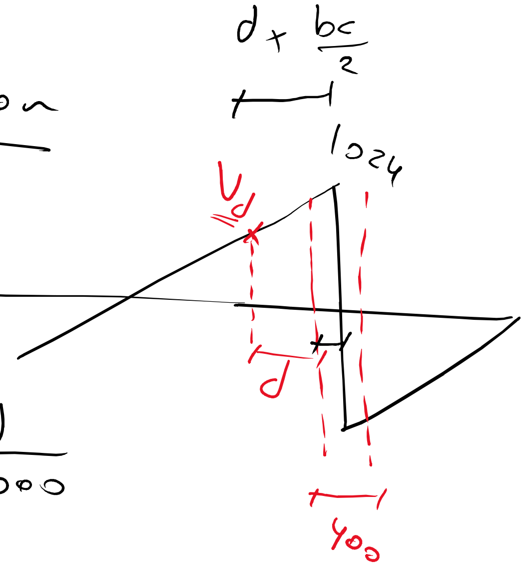


$\Sigma F_z = 0$

$\rightarrow 320 \times 2.3 = V$

$V = 736 \text{ kN}$

Sect 2 is the critical Section



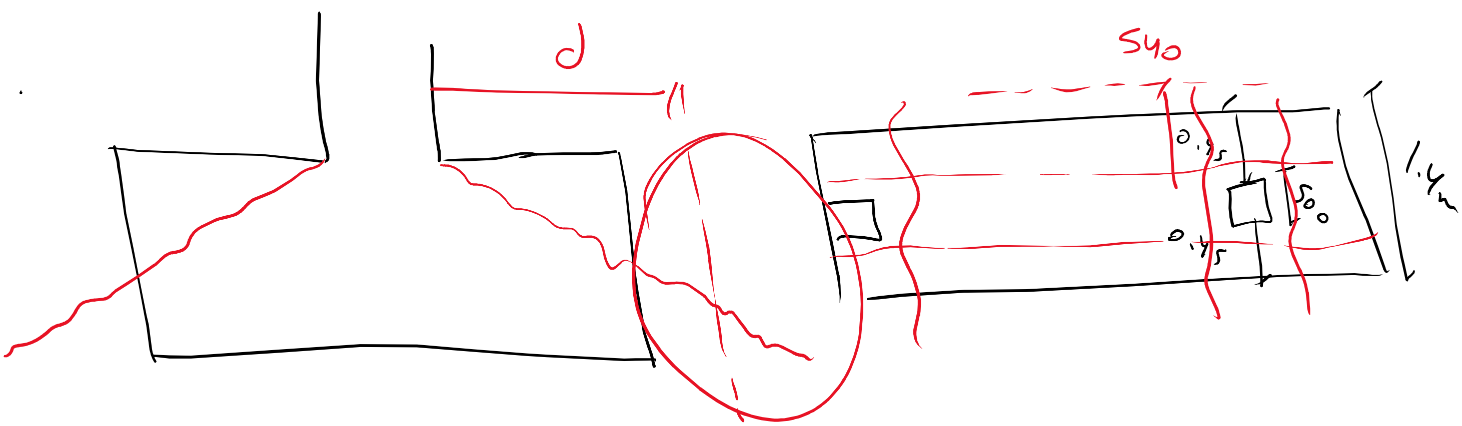
$$V_u = 1024 - 320\left(\frac{0.4}{2} + \frac{d}{1000}\right)$$

$$\phi V_c = 0.75 \times \frac{1}{6}\sqrt{21} \times 1400 \times \frac{d}{1000}$$

$$\phi V_c = V_u$$

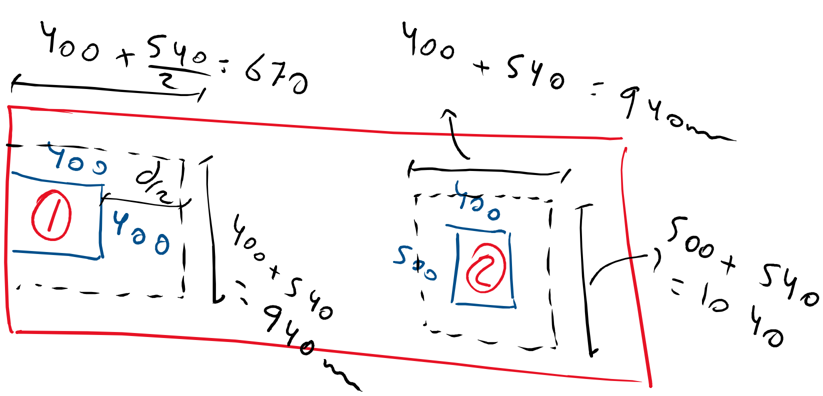
→ $d = 525$ mm → 540 mm

not directly on Soil → $h = 540 + 60 = 600$ mm



Check Punching

$d = 540$ mm



Check Column 1

$b_{o1} = 670 \times 2 + 970 = 2280$ mm.

$\phi V_c = 0.75 \times \frac{1}{3}\sqrt{21} \times \frac{2280 \times 540}{1000} = 1410$ kN.

$\beta = \frac{500}{400} < 2 \rightarrow \left(\frac{1}{3}\right)$

if no moment (or uniform stress)

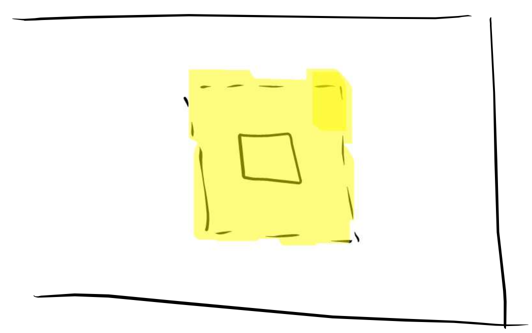
$\phi V_c > P_u > V_u$

if non uniform stress

$\phi V_c > V_u > P_u$

$V_u = 800 - 0.67 \times 0.94 \times 228.2$ (σ_u)

$= 656$ kN $< \phi V_c$ ok



→ Check Column 2

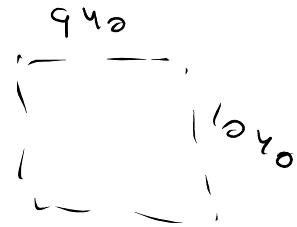
→ $d = 540$

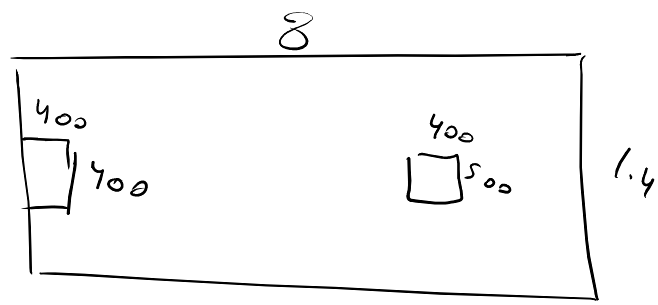
$b_o = 1040 \times 2 + 940 \times 2 = 3960$ mm.

$\phi V_{c_2} = 0.75 \times \frac{1}{3}\sqrt{21} \times \frac{3960 \times 540}{1000} = 2450$ kN.

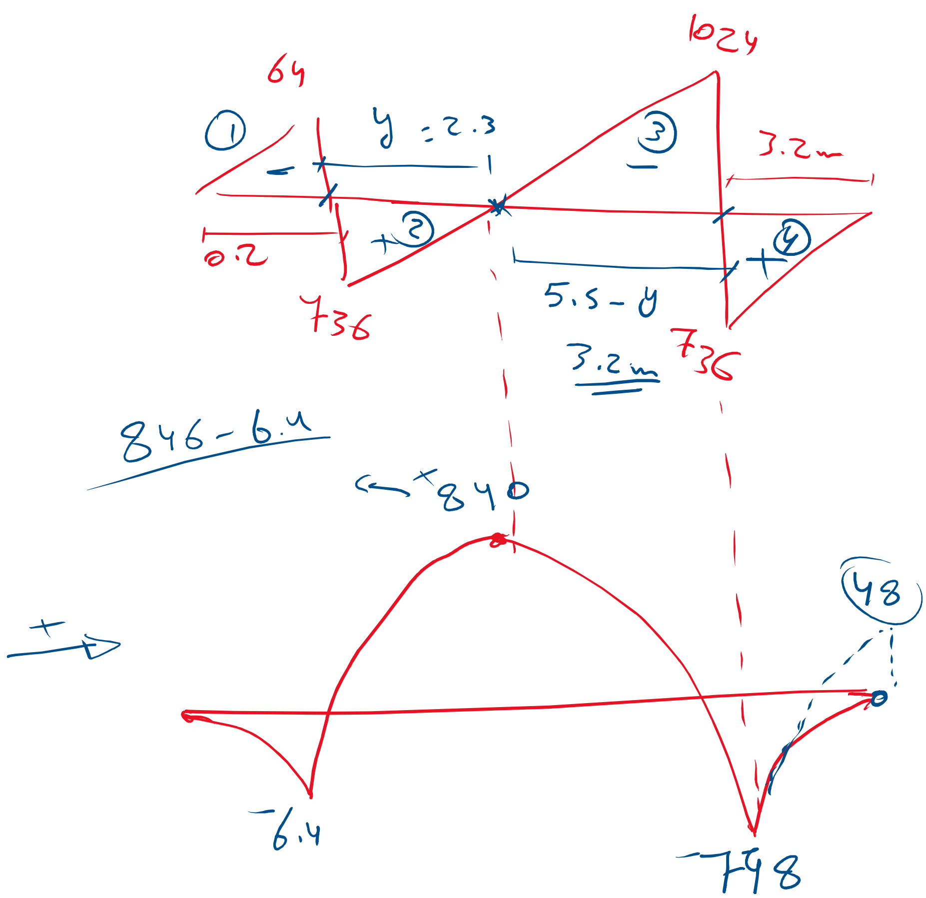
$$V_{u(2)} = 1760 - 228.2 \times (1.04 \times 0.94)$$

$$= 1537 \text{ kN} < \phi V_{c(2)}$$





T = 600 mm



$$\frac{736}{y} = \frac{1024}{5.5 - y}$$

$y = 2.3$ m

$A_{1} = 6.4$

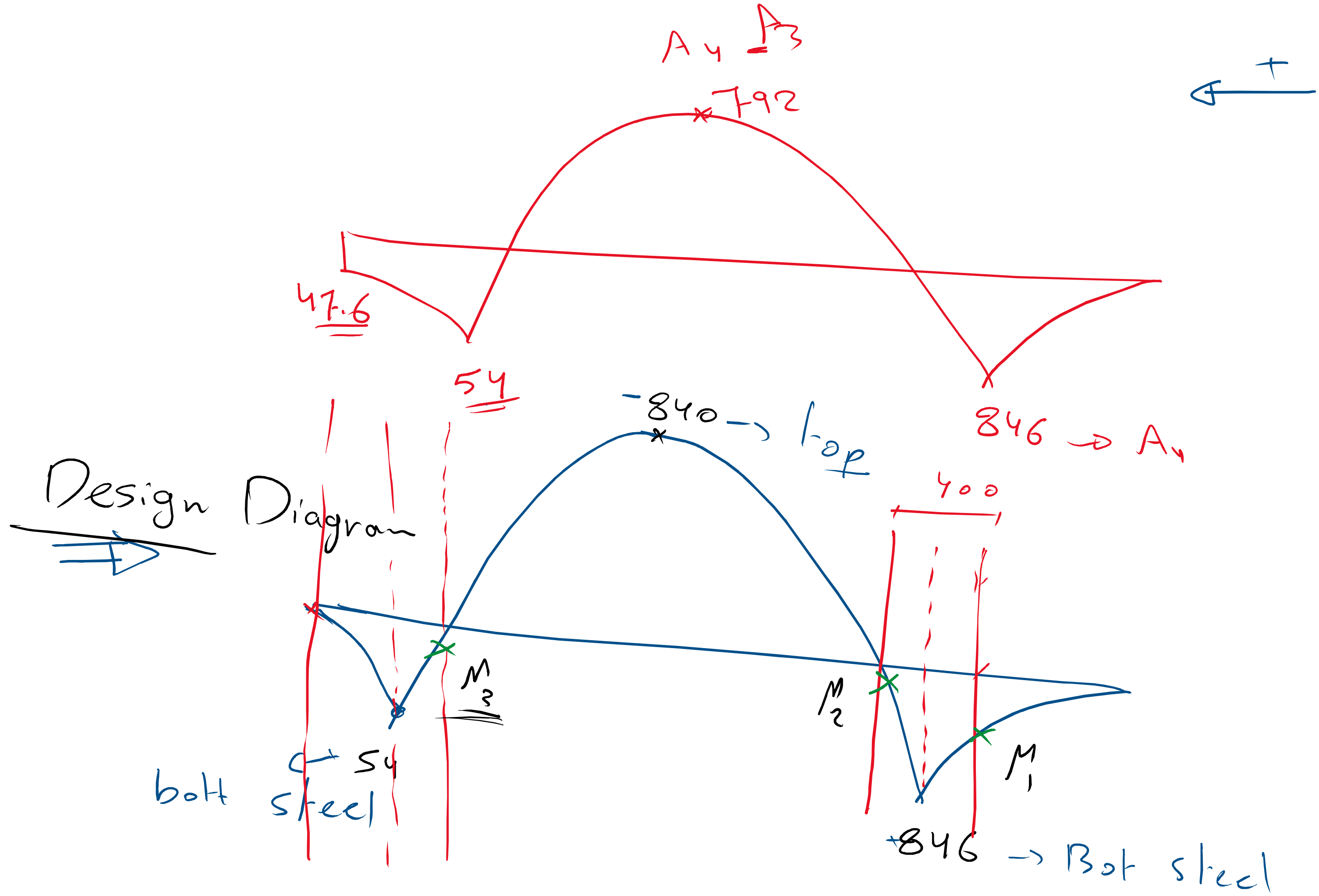
$A_{2} = \frac{1}{2} \times 2.3 \times 736$

$= 846$

$A_{3} = 1638$

$A_{4} = \frac{1}{2} \times 3.2 \times 736$

$= 846$



$M_{mid} = 840$ kN.m → $d = 540$

$b = 1400$ mm.

$\Rightarrow \rho = 5.8 \times 10^{-3}$ → $A_s = bd \times \rho$

$= 4375$ mm^2

Check $A_{s_{min}}$

$A_{s_{min}} = \frac{1.4}{F_y} \times b\,d = 2520$ mm^2 ok

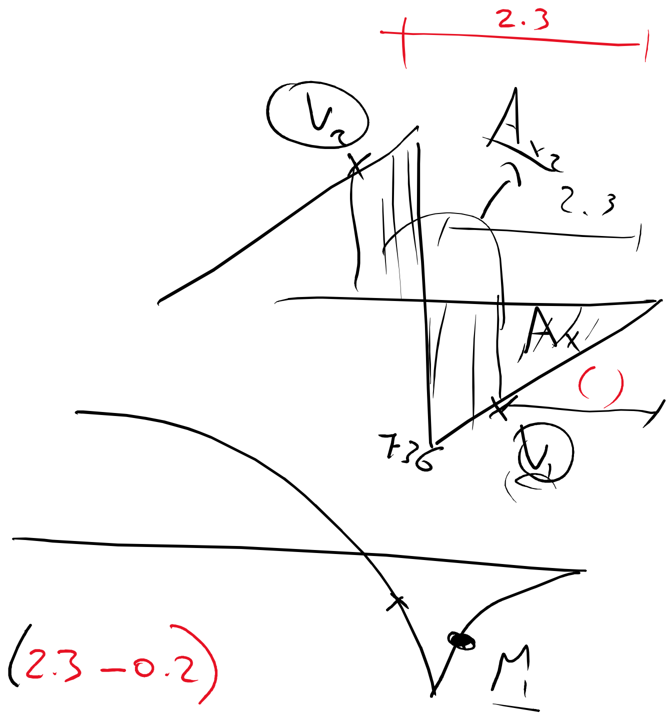
Moment at face of Column 2

Shear at face of C2

$\rightarrow \frac{736}{2.3} = \frac{x}{2.3 - 0.2}$

$x = 672 \text{ kN} \rightarrow V_1$

Moment at V_1 = Area = $\frac{1}{2} \times (672)(2.3 - 0.2)$
$= 706 \text{ kN.m}$



ratio $A_s = \frac{706}{840} \times 4375 = 3677 \text{ mm}^2$

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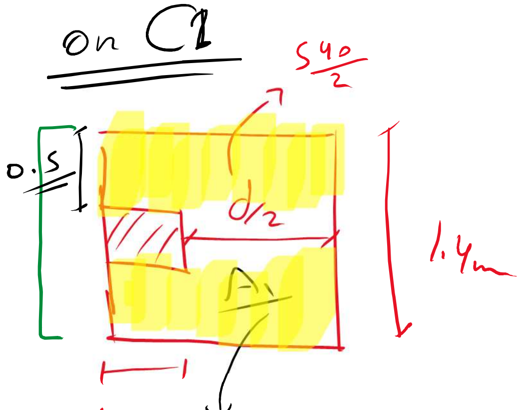
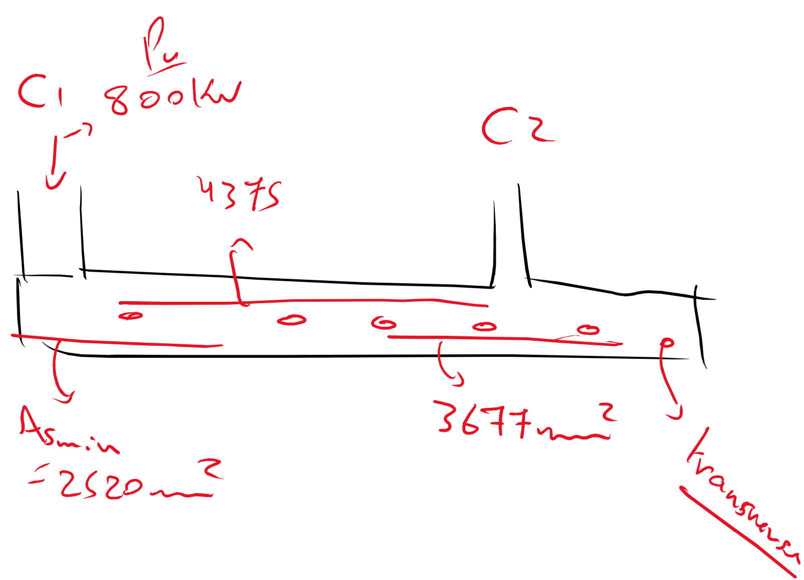
transverse steel

on C1





$\sigma_{u_{C1}} = \frac{P_u}{A_1} = \frac{800}{1.4 \times 0.67} = 853 \text{ kN/m}^2$

$$M_u = \frac{853 \times (0.5)^2}{2} = 106 \text{ kN.m/m}$$

$d = 546$; $b = 1000$

$\rho = 9.77 \times 10^{-4} \rightarrow A_s = 527 \text{ mm}^2/\text{m}$

$$A_{s_{min}} = \overset{0.0018 \times b \times h}{0.0018 \times 1000 \times 600} = \underline{1090 \text{ mm}^2}/\text{m} > A_s$$

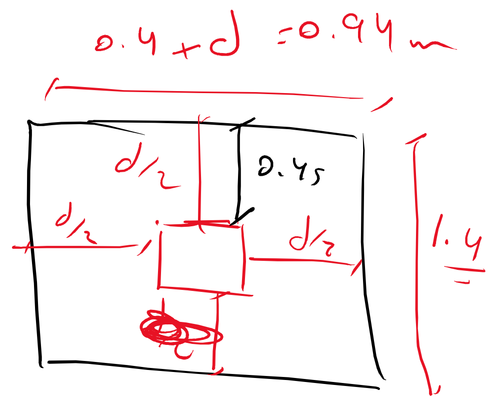
shrinkage.

use $A_{s_{min}}$

Col 2

$P_u = 1760 \text{ kN} \rightarrow \sigma_u = \frac{1760}{1.4 \times 0.94} = 1337 \text{ kN/m}^2$

$$M_u = \frac{1337 \times (0.45)^2}{2} = 135 \text{ kN.m/m}$$



$\rho = 9.77 \times 10^{-4} \rightarrow A_s = 527 \text{ mm}^2/\text{m} < A_{s_{min}}$

$A_{s_{min}} = \overset{6\phi16}{1080} \text{ mm}^2/\text{m} \rightarrow$ Use $A_{s_{min}}$.