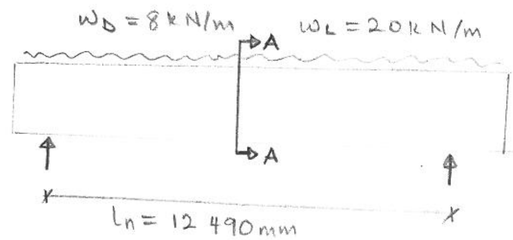
CIVE 3206

Concrete I Assignment 5 T.A : Conrad Kyei



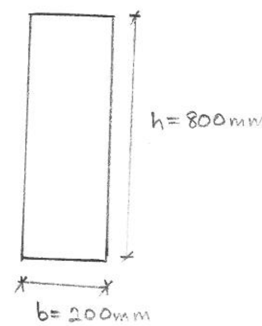
(Unfactored Loads)

$f_c' = 35$ MPa

$f_y = 400$ MPa

Stirrup diameter, $d_s = 10$ mm

Cover = 30mm (beam not exposed)
(pg. 2.6 white pages)



Section A - A

$\alpha_1 = 0.85 - 0.0015 f_c'$

$\alpha_1 = 0.85 - 0.0015(35) \simeq 0.8$

$\beta_1 = 0.97 - 0.0025 f_c'$

$\beta_1 = 0.97 - 0.0025(35) \simeq 0.883$

Maximum Factored Moment

$w_f = 1.25 w_D + 1.5 w_L$

$= 1.25(8) + 1.5(20) = 40$ kN/m

$$M_f = \frac{w_f l_n^2}{8} = \frac{40(12.49)^2}{8} \simeq 780 \text{ kNm}$$

Estimate Effective Depth, d

Assume single layer of reinforcement

$d \cong h - 55 = 800 - 55 = 745$ mm

Determine required tension reinforcement

Use Table 2.1 (White Pages)

Let $M_r \cong M_f = 780$ kNm

$$K_r = \frac{M_r \times 10^6}{bd^2} = \frac{780 \times 10^6}{200(745)^2} = 7.03 \text{ MPa}$$

$\rho \cong 2.79\% = 0.0279$

$$\rho_b = \frac{A_{sb}}{bd} = \frac{\alpha_1 \phi_c f_c' \beta_1}{\phi_s f_y}\left(\frac{700}{f_y + 700}\right)$$

$$\rho_b = \frac{0.8(0.65)(35)(0.883)}{0.85(400)}\left(\frac{700}{400+700}\right) = 0.03 \simeq 3\%$$

Since $\rho = 2.79\% < \rho_b = 3\%$ Steel yields o.k.

$A_s = \rho bd = 0.0279(200)(745) = 4160 \text{ mm}^2$

Compute M_r

From Equilibrium

$$a = \frac{\phi_s A_s f_y}{\alpha_1 \phi_c f_c' b} = \frac{0.85(4160)(400)}{0.8(0.65)(35)(200)} \simeq 390 \text{mm}$$

$$M_r = \phi_s A_s f_y\left(d - \frac{a}{2}\right) = 0.85(4160)(400)\left(745 - \frac{390}{2}\right)$$

$$\simeq 778 \text{ kNm} < M_f$$

=> Additional reinforcement will have to be provided in the form of compression reinforcement.

Using 35M Area of bar, $A_b = 1000 \text{ mm}^2$

Use 4 - 35M in two layers (bottom bars).

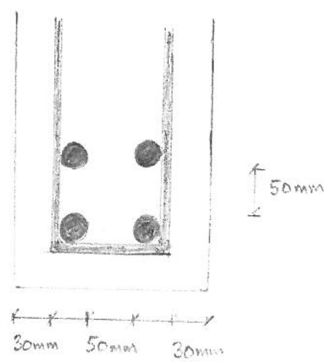
Minimum Bar Spacing   A 23.3 Cl. 6.6.5.2

$$S_{min} = \max. \begin{cases} 1.4 d_b = 1.4(35) = 49 mm \\ 1.4 a_{max} = 1.4(20) = 28 mm \\ 30 mm \end{cases} \approx 49 mm$$

$$b_{min} = (n \times d_b) + (n-1) \times S_{min} + 2 \times d_s + 2 \times cover$$

where n = Number of bars = 2 (per layer)

$$b_{min} = 2(35) + 1(49) + 2(10) + 2(30) = 199 mm \approx 200 mm$$



$$d_1 = 800 - 30 - 10 - \frac{35}{2} = 742.5 mm$$

$$d_2 = d_1 - 50 - 35 = 657.5 mm$$

$$d = \frac{2(1000)(742.5) + 2(1000)(657.5)}{4(1000)}$$

$$d = 700 mm$$

Moment of Resistance Provided by Tension Steel Only (Assume steel yield)

$$M_r = \phi_s A_s f_y \left(d - \frac{a}{2} \right)$$

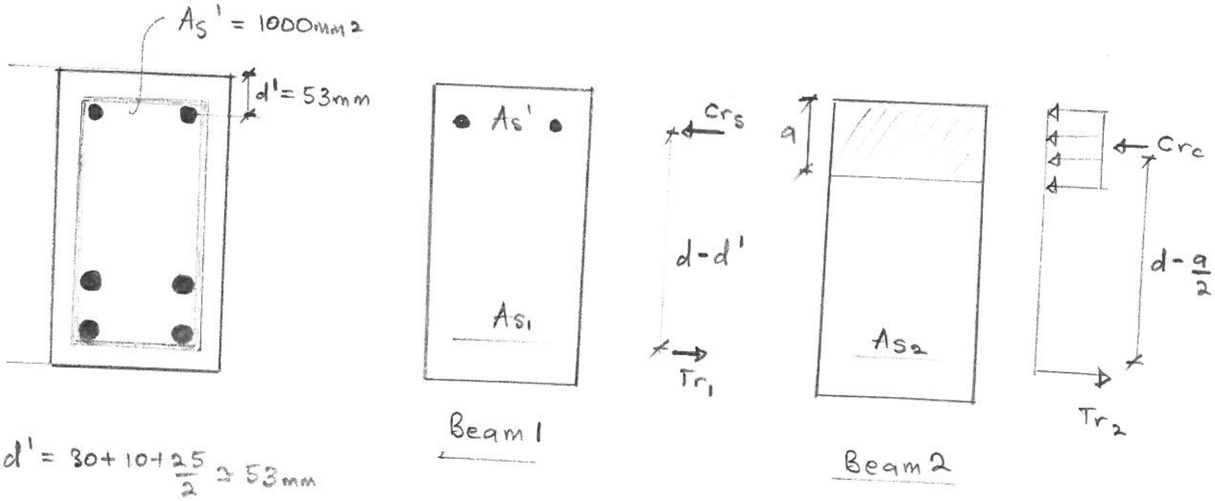
$$a = \frac{\phi_s A_s f_y}{\alpha_1 \phi_c f_c' b} = \frac{0.85(4000)(400)}{0.8(0.65)(35)(200)} = 374 mm$$

$$M_r = 0.85(4000)(400) \left(700 - \frac{374}{2} \right) = 698 kNm$$

Extra Moment of Resistance Required

$$> 780 - 698 = 82 kNm$$

Try 2 - 25M bars (in compression)



$d' = 30 + 10 + \frac{25}{2} \simeq 53mm$

Assuming compression and tension steel yields

$$f_s' = f_s = f_y$$

From Beam 1

$$C_{rs} = T_{r_1}$$

$$\phi_s A_s' f_y = \phi_s A_{s_1} f_y$$

$$\Rightarrow A_s' = A_{s_1} = 1000mm^2$$

$$M_{r_1} = \phi_s A_s' f_y (d - d') = 0.85(1000)(400)(700-53)$$

$$\simeq 220 \, kNm$$

From Beam 2

$$A_{s_2} = A_s - A_s' = 4000 - 1000 = 3000 \, mm^2$$

$$a = \frac{\phi_s A_s f_y}{\alpha_1 \phi_c f_c' b} = \frac{0.85(3000)(400)}{0.8(0.65)(35)(200)} = 264mm$$

$$M_{r_2} = \phi_s A_{s_2} f_y \left(d - \frac{a}{2}\right) = 0.85(3000)(400)\left(700 - \frac{264}{2}\right)$$

$$\simeq 580 \, kNm$$

$$M_r = M_{r_1} + M_{r_2} = 220 + 580 = \underline{800\,kNm} > M_f\ (780\,kNm)$$

O.K.

Check Yield of Compression Steel

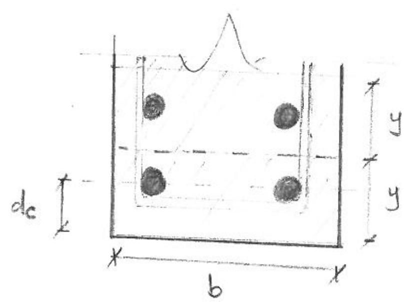
$$\frac{d'}{a} = \frac{53}{264} \simeq 0.2 \qquad \left(\frac{d'}{a}\right)_{lim} = \frac{1}{\beta_1}\left(1 - \frac{f_y}{700}\right)$$

$$\left(\frac{d'}{a}\right)_{lim} = \frac{1}{0.88}\left(1 - \frac{400}{700}\right) \simeq 0.49$$

Since $\left(\frac{d'}{a}\right) < \left(\frac{d'}{a}\right)_{lim}$ Compression steel Yields

O.K.

Crack Control Parameter Check (z) A23.3 Cl. 10.6.1



$$d_c = 30 + 10 + \frac{35}{2} = 57.5\,mm$$

$$y = h - d = 800 - 700 = 100\,mm$$

Total Effective Tension Area,

A_e = Shaded Area

$$A_e = b(2y) = 200(2)(100) = 40000\,mm^2$$

$$A = \frac{A_e}{\text{No. of bars}} = \frac{40\,000}{4} = 10\,000\,mm^2$$

$$f_s = 0.6 f_y = 0.6(400) = 240\,MPa$$

$$z = f_s (d_c A)^{1/3} = 240\left((57.5)(10\,000)\right)^{1/3} = 19\,960\ N/mm$$

Since $z = 19\,960\ N/mm < 30\,000\ N/mm$ (not. exposed)

$\therefore$ OK.

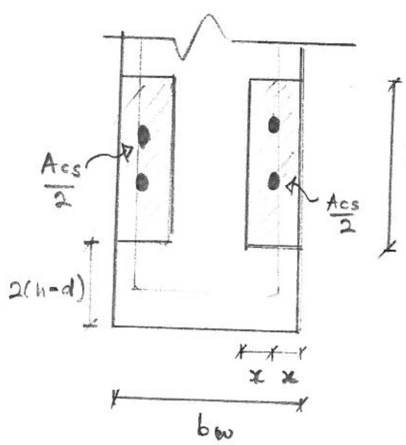
For deep flexural members, crack control check may not be sufficient to control cracking near mid-depth.

Skin Reinforcement (Table 2.8 white pages.)

Since $h > 750mm$ skin reinforcement needs to be provided to control near mid-depth crack.

$$A_{sk} = \rho_{sk} A_{cs}$$

$$\rho_{sk} = 0.008 \text{ (for Interior Exposure)}$$



$$\frac{h}{2} - 2(h-d) = \frac{800}{2} - 2(800-700)$$

$$= 400 - 200$$

$$= 200mm$$

Use 15M bars for skin rebars

$$x = 30 + 10 + \frac{15}{2} = 47.5mm \leq \frac{b_w}{4}$$

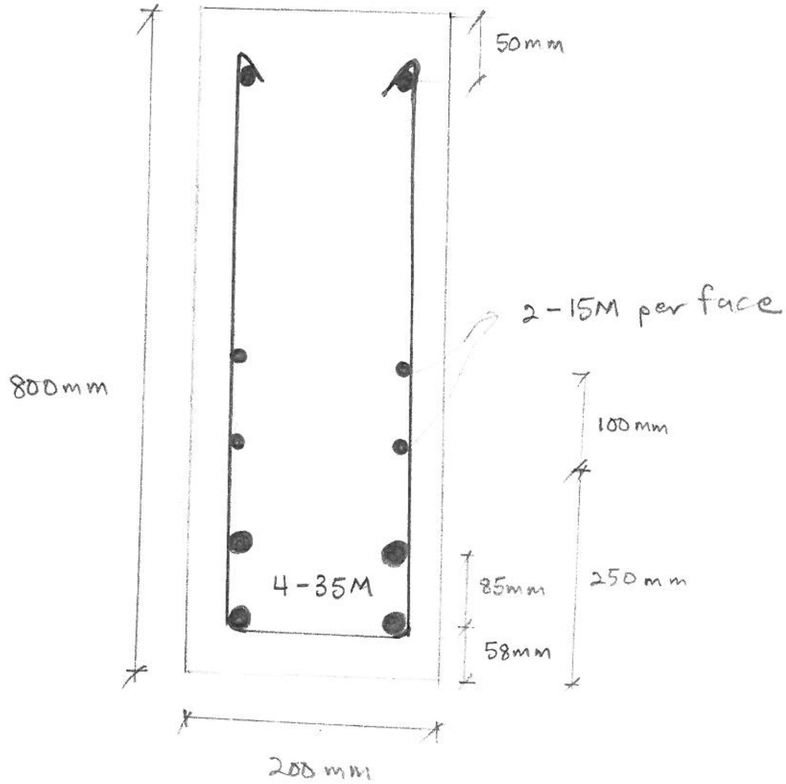
$$\frac{b_w}{4} = \frac{200}{4} = 50mm \text{ O.K.}$$

$$\frac{A_{cs}}{2} = \left(\frac{h}{2} - 2(h-d)\right)(2x) = 200(2)(47.5) = 19000 mm^2$$

$$A_{sk} = 0.008(20000) = 152 mm^2 \text{ (per face)}$$

Use 2-15M per face = $400 mm^2$ per face

Maximum spacing = $200 mm^2$


50mm
2-15M per face
800mm
100mm
4-35M
85mm
250mm
58mm
200mm

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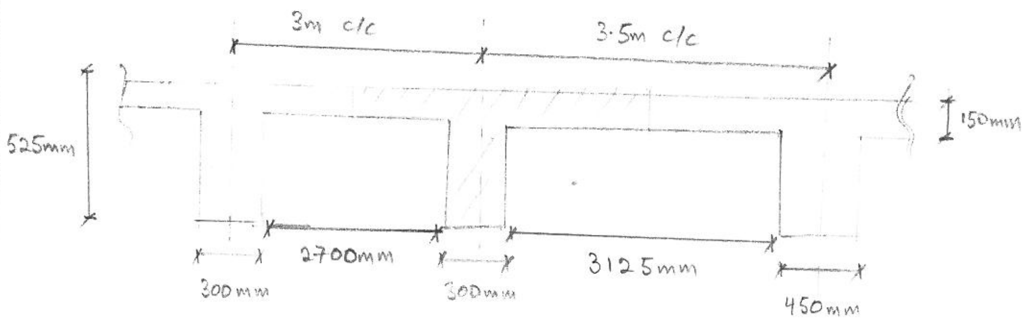
Question 2

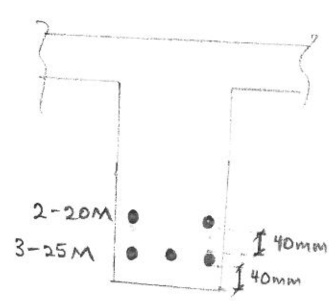
Span Length, l_n = 8000mm

Assume beam is simply supported

Using A 23.3 Cl. 10.3.3, over-hung flange width on each side of web, should be:

lesser of
- 1/5 × span length (for simply supported beam;
- 12 × flange thickness ;
- 1/2 × clear distance to next web;





$A_s = 2100 mm^2$

$f_c' = 25MPa$

$f_y = 400 MPa$

Thickness of flange, $h_f = 525mm$

$\phi_s = 0.85$

$\phi_c = 0.65$

$\alpha_1 = 0.85 - 0.0015 f_c' = 0.813$

$\beta_1 = 0.97 - 0.0025 f_c' = 0.908$

Concrete cover = 40mm

b_T = 300mm

Over-hang flange width,

b_T' (left)

$\frac{1}{5} \times l_n = \frac{1}{5}(8000) = 1600\text{mm}$

$12 h_f = 12(150) = 1800\text{mm}$

$\frac{1}{2} \times$ clear dist. to left web $= \frac{1}{2} \times 2700 = \underline{1350\text{ mm}}$

b_T' (right)

$\frac{1}{5} \times l_n = \frac{1}{5}(8000) = 1600\text{mm}$

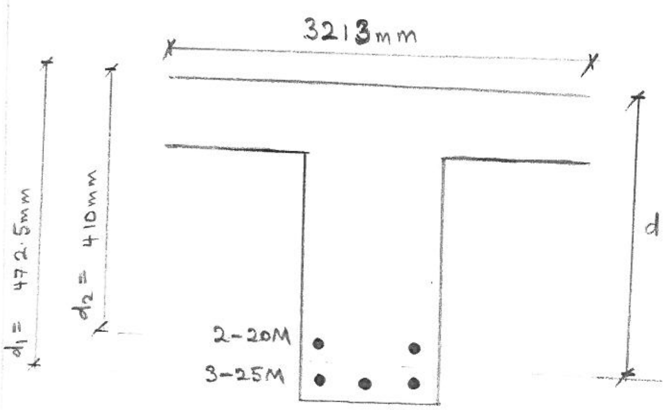
$12 h_f = 12(150) = 1800\text{mm}$

$\frac{1}{2} \times$ clear dist. to right web $= \frac{1}{2} \times 3125 = \underline{1563\text{ mm}}$

Flange Width.

$b = 300 + 1350 + 1563 = \underline{3213\text{mm}}$

Determine Effective Depth, d



$$d = \frac{3(500)(472.5) + 2(300)(410)}{3(500) + 2(300)}$$

$d = \underline{455\text{mm}}$

Area of 20mm bar = 300mm²

Area of 25mm bar = 500mm²

$d_1 = 525 - 40 - \frac{25}{2} = 472.5\text{mm}$

$d_2 = 525 - 40 - 25 - 40 - \frac{20}{2} = 410\text{mm}$

Check minimum reinforcement

$$A_{smin} = \frac{0.2\sqrt{f_c'}}{f_y} b_t h = \frac{0.2\sqrt{25}}{400}(300)(525) = 395 mm^2$$

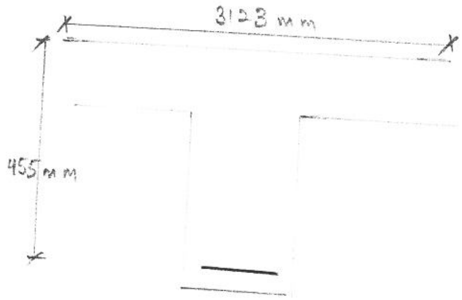
$$A_{sprov} = 2(300) + 3(500) = 600 + 1500 = 2100 mm^2$$

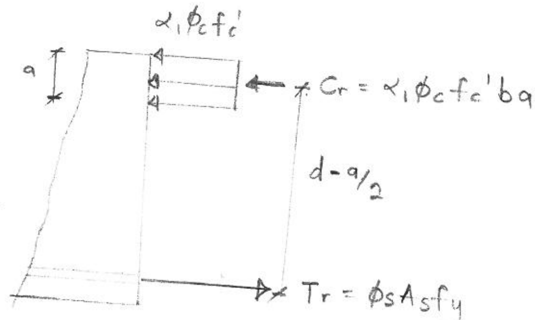
$A_{sprov} > A_{smin}$ O.K.

Compute a

Assume depth of compression stress block a is less than h_f.

Assume steel has yielded.





For Equilibrium

$C_r = T_r$

$\alpha_1 \phi_c f_c' b a = \phi_s A_s f_y$

$$a = \frac{\phi_s A_s f_y}{\alpha_1 \phi_c f_c' b} = \frac{0.85(2100)(400)}{0.813(0.65)(25)(3213)} \simeq 16.8 mm$$

Since $a = 16.8 mm < h_f = 150 mm$

Compression zone is rectangular

Check Steel Yielding

$$\frac{a}{d} = \frac{16.8}{455} = 0.037$$

$$\frac{a_b}{d} = \frac{1}{\beta_1}\left(\frac{700}{700+f_y}\right) = \frac{1}{0.908}\left(\frac{700}{700+400}\right) = 0.701$$

Since $\frac{a}{d} = 0.037 < \frac{a_b}{d} = 0.701$ Steel Yields O.K.

Moment of Resistance

$$M_r = T_r\left(d - \frac{a}{2}\right) = \phi_s A_s f_y\left(d - \frac{a}{2}\right)$$

$$= 0.85(2100)(400)\left(455 - \frac{16.8}{2}\right)$$

$$M_r \simeq 319 \text{ kNm}$$

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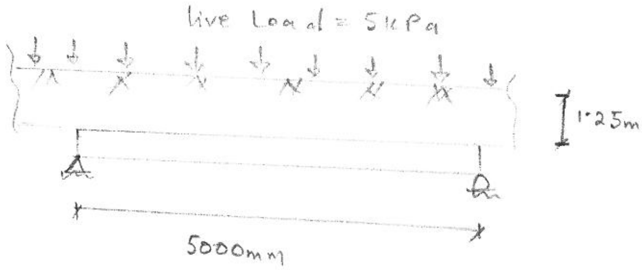
Question 3



$f_c' = 30MPa$

$f_y = 400MPa$

$\alpha_1 = 0.85 - 0.0015 f_c' = 0.805$

$\beta_1 = 0.97 - 0.0025 f_c' = 0.895$

$\gamma_{conc} = 24 kN/m^3$

From pg. 1-56 $\gamma_{soil} = 18.9 kN/m^3$ (For sand and gravel, wet)

Estimate Slab Thickness

minimum thickness $= \frac{l_n}{20} = \frac{5000}{20} = 250mm$

=> we can use $h = 300mm$

Since slab is a one way slab a metre width is considered

Compute factored Moment

$w_{LL} = 5kN/m$

Super imposed DL, $w_{SDL} = 18.9(1.25) = 23.6 kN/m$ /metre width

Self weight of slab $= 24(0.3) = 7.2 kN/m$ /metre width

$w_{DL} = 23.6 + 7.2 = 30.8 kN/m$

$w_f = 1.25(30.8) + 1.5(5) = 46 kN/m$

$M_f = \frac{w_f L^2}{8} \doteq \frac{46(5)^2}{8} = 144 kNm$

Estimate Effective Depth

Use cover = 30mm

25M bars => $d = h - cover - \frac{d_b}{2}$

No stirrups

$d = 300 - 30 - \frac{25}{2} \simeq 258mm$

Compute required area of tension reinforcement, A_s

=> Use Table 2.1 (in white pages)

Take $M_r = M_f = 144\,kNm$

$$K_r = \frac{M_r \times 10^6}{bd^2} = \frac{144 \times 10^6}{1000(258)^2} = 2.16\ MPa$$

=> $\rho = 0.688\% \simeq 0.007$

$$\rho_b = \frac{A_{sb}}{bd} = \frac{\alpha_1 \phi_c f_c' \beta_1}{\phi_s f_y}\left(\frac{700}{f_y + 700}\right)$$

$$= \frac{0.805(0.65)(30)(0.895)}{0.85(400)}\left(\frac{700}{400+700}\right)$$

$$= 0.026$$

Since $\rho = 0.007 < \rho_b = 0.026$ Steel Yields o.k.

$\rho = \frac{A_s}{bd}$ $A_s = \rho b d$

$A_s = 0.007(1000)(258) \simeq 1806\ mm^2$

Bar Spacing

$$s \leq A_b\left(\frac{1000}{A_s}\right) = 500\left(\frac{1000}{1806}\right) \simeq 275\,mm \text{ spacing}$$

=> Provide 25M bars @ 250mm spacing.
(4 bars per metre width)

$A_{s\,prov} = 500 \times 4 = 2000\,mm^2/m$

Minimum Reinforcement Check

$A_g = b \times h = 1000(300) = 300\,000 \text{ mm}^2$

$A_{s\,min} = 0.002 A_g = 0.002(300\,000) = 600 \text{ mm}^2/\text{m}$

$A_{s\,prov} = 2000 \text{ mm}^2/\text{m} > A_{s\,min} = 600 \text{ mm}^2/\text{m}$ O.K.

Maximum Bar Spacing Check

$$S_{max} = \text{less of} \begin{cases} 3h = 3(300) = 900\text{mm} \\ 500\text{mm} \end{cases} = 500\text{mm}$$

$S_{max} = 500\text{mm} > s = 250\text{mm}$ O.K.

Moment Capacity Check

$$M_r = \phi_s A_s f_y \left(d - \frac{a}{2}\right)$$

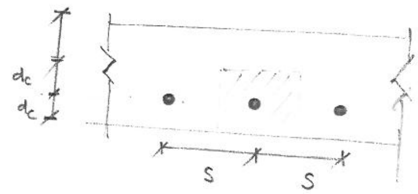
$$a = \frac{\phi_s A_s f_y}{\alpha_1 \phi_c f_c' b} = \frac{0.85(2000)(400)}{0.805(0.65)(30)(1000)} = 43.3\text{mm}$$

$$M_r = 0.85(2000)(400)\left(258 - \frac{43.3}{2}\right) = 161 \text{ kNm}$$

Since $M_r = 161 \text{ kNm} > M_f = 144 \text{ kNm}$ O.K.

Crack Parameter Check (z)

$d_c = 30 + \frac{25}{2} = 42.5\text{mm}$



$A = s\,(2d_c) = 250(2)(42.5)$

$A = 21250\text{mm}^2$

Stress in steel under service load level,

$f_s = 0.6 f_y = 0.6\,(400) = \underline{240\text{MPa}}$

$z = f_s\,(d_c A)^{1/3}$

$z = 240\,\left((42.5)(21250)\right)^{1/3} = 23200\ \text{N/mm}$

$z = 23200\,\text{N/mm} < 30000\,\text{N/mm}$ $\underline{\text{o.k.}}$

Shrinkage and Temperature Reinforcement

Provide As_{min} transverse reinforcement for shrinkage and temperature. Use 20M bars, $A_b = 300\text{mm}^2$

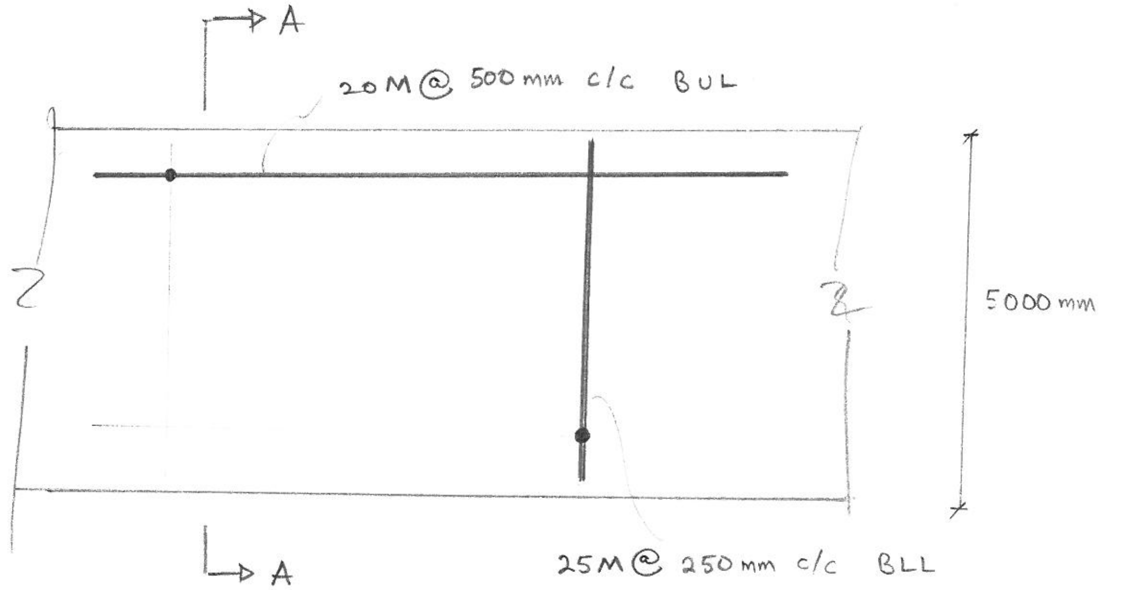
$S_{max} = \text{less of} \begin{cases} 5h = 5(300) = 1500\text{mm} \\ 500\text{mm} \end{cases} = \underline{500\text{mm}}$

$S_{max} = 500\text{mm}$

$As_{min} = 0.002 A_g = 600\text{mm}^2/\text{m}$

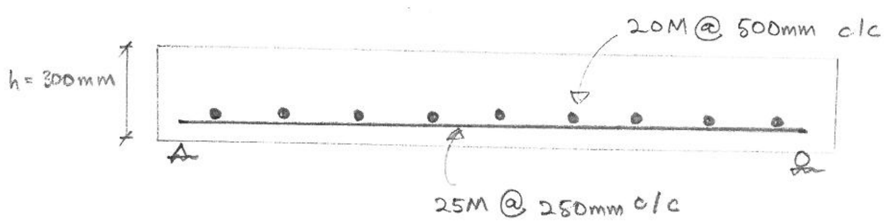
$S \leq A_b \left(\frac{1000}{A_s}\right) = \frac{300(1000)}{600} = 500\text{mm}$

Provide 20M @ 500mm



PLAN VIEW OF SLAB

BLL = Bottom Lower Layer
BUL = Bottom Upper Layer



Section A - A

30mm clear cover to 25M Bars