Civilittee
اللجنة الأكاديمية لقسم الهندسة المدنية
www.Civilittee-HU.com

دفتر

خرسانة مسلحة1

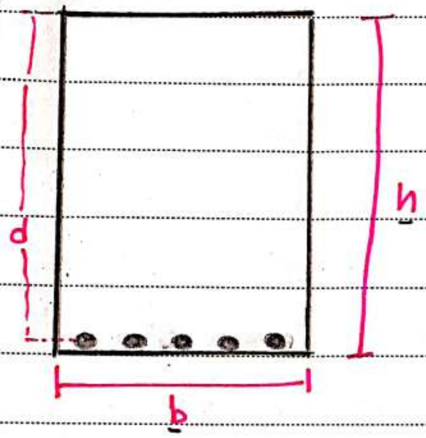
د. بلال ابو الفول

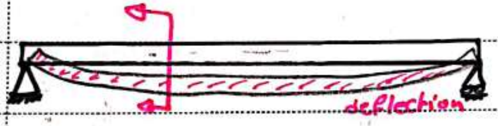
إعداد : رقية فتحي

"The Design"

→ Design of Rect-beam.

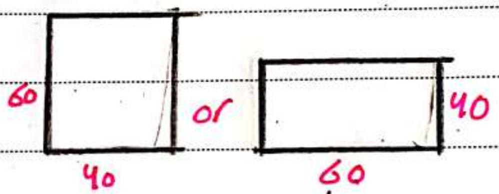
→ (b , h , A_s , A_s')





+ve M تسليح سفلي

"sections"



يعطي I اعلى

$I = \frac{40 \times 60^3}{12}$

⇓

h اعلى ← I اعلى ← deflection اقل

$I = \frac{60\ 40^3}{12}$

⇘

h اقل ← I اقل ← deflection اعلى

⇒ for the relationship between beam depth and deflection → use Table 9.5.

⇒ To avoid deflection Calculation :-

"طول ال span الأصلي"

$$h_{min}\,(S.S.B) = \frac{L}{16} = \frac{8000\,mm}{16} = 500\,mm$$

simply supported beam.

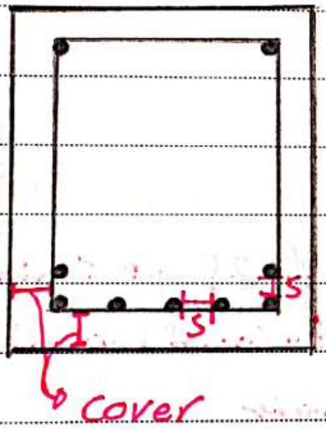
* ما بقدر امنع الـ deflection بس بقدر احطلو limit حسب الـ ACI code :

→ $h_{min} = 50$ cm   "عمون القاعدة"

↳ and $h = 45$ cm → h اقل من hmin عادي ← بس لازم اعمل check على الـ deflection إذا OK او ✗ ← وإذا التزمت بـ 50cm الـ minimum ما بعمل check على الـ deflection.

* Concrete Cover and Bar spacing.

- Cover



* اسباب وجود الـ Cover.

1) بعطي قيمة اعلى للـ bond مع الـ Concrete.

2) يحمي الحديد من الصدأ.

3) يحمي الحديد من اثار الحريق (مشان ما يصير yield بسرعة).

$Cover_{min}$ = 40mm (Normal exposure)

- Bar spacing

- horizontal spacing.

s_{min} = larger of {
Bar diameter
25 mm
1.33 max size of coars agg
diameter of vibrator (desirable not specified)

= vertical spacing

$$S_{min} = \text{larger of} \begin{cases} 25\ mm \\ 1.33\ \text{max size of C.A} \end{cases}$$

$$\underbrace{5}_{\text{No. of bars}}\ \underbrace{\text{No. 25}}_{\text{diameter of bar}}\ \underbrace{M}_{\text{Meber}}$$

لأنو ما اعطاني
معلومات عن نقطة ٣و٤
اخذت 25

$$b_{min} = \underbrace{2}_{\text{على الجنبين}} \ast \underbrace{40}_{\text{Cover}} + 2 \ast \underbrace{10}_{\text{الكانة diameter}} + \underbrace{5}_{\text{No. of bars}} \ast \underbrace{25}_{\text{diameter of bars}} \ast \underbrace{4}_{s = (\text{no. of bars} - 1)} \ast \underbrace{25}_{\rightarrow S_{min}}$$

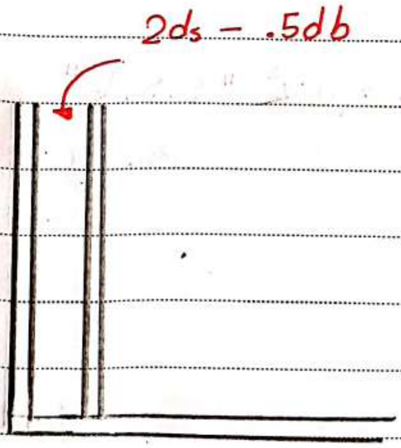
$= 325\ mm$

$\Rightarrow$ if $b > b_{min}$ (one layer)

$b < b_{min}$ (Two layers)

* افرض
بطلعت 2layers وعندي 5 قضبان
افضل احط 3 تحت و2 فوق
مشان تربطهم بنفس الكانة وما
بزيد الكلفة.

* لو طلع عندي الحديد Two layers مش شرط احطهم على طبقتين
ممكن احطهم بطبقة وحدة ← إذا زدت قطر الـbar (مش افضل لأنو
إذا قللتو بقل الـdiameter وبزيد عدد الـbars وبالتالي الـs وهيك بزيد bmin ←)
بقل عدد الـbars وبالتالي عدد s ← وبقل bmin .



$\Rightarrow b_{min} = 2 * \text{cover} + 2 * \text{stirps diameter} + (n)\text{No. of bars} * \text{diam of bars} + (n-1) * S_{min} + 2(2d_s - .5d_b)$

* Estimating the effective depth of the beam (d)

$d = h - 65\,mm$ "if one layer"

$d = h - 90\,mm$ "if Two layer"

* bmin should not be Less than 300 mm.

* $A_s = \dfrac{M_u}{\phi f_y (jd)}$

ϕ → .9

j = .9 "for narrow comp area" rect. beam and T-beam "web in comp"

j = .95 " for wide comp area" T-beam "flange in comp".

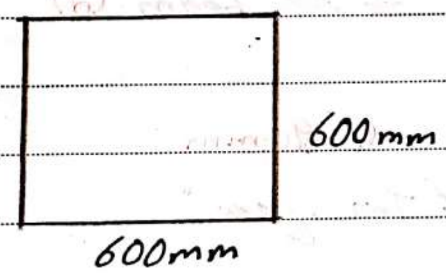
- $U = 1.2DL + 1.6LL$ → $M_u = \frac{wL^2}{8}$ "S.S.b"

$M_u = \frac{wL^2}{2}$ "Cantilever"

- $a = \frac{A_s f_y}{.85 f_c' b}$

* $\phi M_n = M_u$ * self.wt = $b * h * \gamma$

⇒ Design example :-



$f_c' = 20$ Mpa

$f_y = 420$ Mpa

$LL = 35$ KN/m $DL = 14$ Kn/m

$\gamma = 24$ KN/m (excluding self.wt)

→ self.wt = $\gamma * b * h$ → $24 * 600 * 600 = 8.64$ KN/m

$DL = 8.64 + 14 = 22.64$ KN/m

$U = 1.2\,DL + 1.6\,LL = 83.2$ KN/m

$M_u = \frac{wL^2}{8} = 665.2$ KN.m

* "Assume one layer"

↳ $d = h - 65 = 535$ mm

NO.

$Mu = 665.6 \ KN.m$

⇒ Iterations :-

$$A_s = \frac{Mu}{\phi f_y \underbrace{jd}_{\to (d - a/2)}} = 3657 mm^2$$

.9 → 535mm (assume one layer → d = h − 65)

$$\to a = \frac{A_s f_y}{.85 f'_c b} = \frac{3657 * 420}{.85 * 20 * 600} = 150.6 mm$$

$$\to A_s = \frac{665.6 * 10^6}{.9 * 420 (535 - \frac{150.6}{2})} = 3830.4 mm^2$$

$$\to a = \frac{3830.4 * 420}{.85 * 20 * 600} = 157.7 mm$$

$\to A_s = 3860.3$

$a = 159 mm$

$[A_s = 3865.6 \ mm^2] \to$ required ⇒ $\phi Mn = Mu$ بتحقق

$[8 \ No.25 M \ ; \ A_s = 4080 \ mm^2]$ (provided) ⇒ $\phi Mn \geq Mu$ بتحقق
(اكبر من required)

$6 \ No.29 M \ ; \ A_s = 3870 mm^2$

$$\Rightarrow b_{min} = 2*40 + 2*10 + 8*25 + 7*25 + 2(2*10 - 0.5*25)$$

$$= 490 mm$$

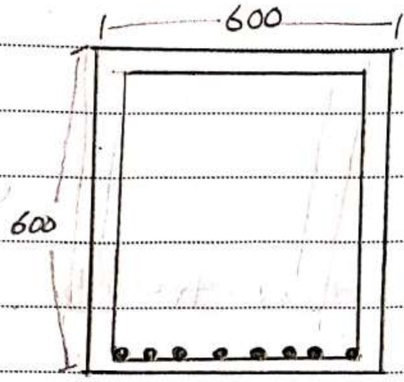
"one-layer is ok"

إذا طلع 2-layers ←

① برجع اعيد الحسابات على assume 2-layers $(d = h - 90)$

أو

② بقلل عدد البارز ← بتالي يقل عدد الـ s



$A_s = 4080\ mm^2$

$T = C_c$

$$a = \frac{4080 \times 420}{.85 \times 20 \times 600} = 168\,mm$$

Check $A_{smin} = \begin{cases} 854\ mm^2 \\ 1070\ mm^2 \end{cases}$] A_{smin}

$A_s = 4080 > A_{smin} \Rightarrow$ OK

* إذا طلعت
$A_s < A_{smin}$
* بوخذ $A_{s_{min}}$ بدل
$A_{s\,required}$ →
وبدخل فيها على الجدول
عشان تحدد كمية
الحديد .

$\Rightarrow\ C = 197.6\,mm$

$$\varepsilon_s = .003 \left(\frac{535-197.6}{197.6}\right) = .0051$$

" $\varepsilon_s > .005 \Rightarrow$ "Tension controlled" " →

* إذا ما طلع هيك برجع
بحل السؤال على اساس انو
doubly reinforcement (A_s, A'_s

$\phi M_n = \phi A_s f_y (d - a/2)$

$.9 \times 4080 \times 420 \left(535 - \frac{168}{2}\right)$

$\phi M_n = 695.6\ KN.m > M_u \Rightarrow$ OK

* "Design (b, h, As are not Known)

* $T = C_c$

$$a = \frac{A_s f_y}{.85 f_c' b}$$

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

bd] → concret section

↳ steel ratio reinforcement ratio.

$$\Rightarrow a = \frac{\rho \cancel{b} d f_y}{.85 f_c' \cancel{b}}$$

$$a = \underbrace{\rho \frac{f_y}{f_c'}}_{\omega \text{ = mechnical steel ratio.}} \frac{d}{.85}$$

$$\Rightarrow a = \frac{\omega d}{.85}$$

$$\phi M_n = M_u$$

$$\phi .85 f_c' ab \left(d - \frac{a}{2}\right) = M_u$$

$$M_u = \phi [bd^2 \underbrace{f_c' \omega (1 - 0.59\omega)}_{K_n \; R_n \text{ flexural resistance factor}}]$$

$$M_u = \phi b d^2 K_n$$

$$* \left[bd^2 = \frac{M_u}{\phi K_n} \right]$$

"Estimate self weight of rect. beams"

1- self. wt = (10-15 %) of the unfactored loads.
$= (10-15\%)(DL + LL)$

2- $h \simeq (\frac{1}{18} - \frac{1}{12})$ of the span length of the beam.

$b = .5h$

$\hookrightarrow$ self.wt $= b * h * \gamma$

* selection of steel ratio (ρ)

1- Economic consideration

"$\rho = 0.01$"

2- Ductility cosideration

$$.35\rho_b \leq \rho \leq .4\rho_b$$

$\rightarrow \underbrace{\rho_b}_{\text{balanced steel}} = \frac{A_{sb}}{bd}$ $\hookrightarrow$ balanced area "$\varepsilon_s = \varepsilon_y$"

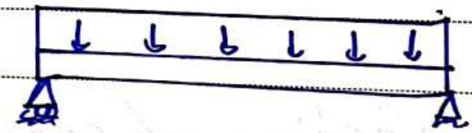
$$\rho_b = \frac{.85 f_c' \beta_1}{f_y}\left(\frac{.003}{.003 + \varepsilon_y}\right) = \frac{.85 f_c \beta_1}{f_y}\left(\frac{600}{600 + f_y}\right)$$

3- By placing consideration

⇒ It may be hard to place the reinforcement if $\rho_{exceeds}$ = 1.5% → ρ_{max}

* Example :→

LL = 25.5 KN/M
DL = 14.5 KN/m
(excluding self wt)



f_y = 420 Mpa γ = 24 KN/m f'_c = 25 Mpa

$$\Rightarrow \quad bd^2 = \frac{M_u}{\phi K_n}$$

$$A_s = \frac{M_u}{\phi f_y jd}$$

$$M_u = \frac{wL^2}{8}$$

1→ self wt = $(10-15\%)\ (\overset{40}{\overline{DL+LL}})$

$(4-6)$ kN/m

[or]

2→ $h \simeq \left(\frac{1}{18} - \frac{1}{12}\right) * 10\ m = \overset{800\ mm}{\overbrace{(555.6 - 833.3)}}$

$b \simeq .5h = \overset{400mm}{\overbrace{(277 - 416)}}$

→ self wt = $.4 * .8 * 24 = 7.68$ KN/m

→ assume self wt = 8KN/m

$W_u = 1.2(14.5+8) + 1.6 * 25.5 = 67.8$ KN/m

$$M_u = \frac{67.8 * (10)^2}{8} = 848 \text{ KN.m}$$

⇒ $\rho = 0.01$

$$w = \frac{\rho f_y}{f'_c} = 0.01 * \frac{420}{25} = 0.168$$

$\phi K_n = \phi(f'_c\, w\,(1 - 0.59\, w))$

$= .9\,(25 * 0.168\,(1 - .59 * .168))$

$\phi K_n = 3.41$ Mpa

→ $$bd^2 = \frac{848 * 10^6\ N.mm}{3.41\ \frac{N}{mm^2}} = 248.7 * 10^6\ mm^3$$

* assume $b = 300mm$; $d = 910mm$

or [$b = 400mm$; $d = 788mm$]

$b = 450mm$; $d = 743mm$

* assume 2 Layer of A_s

$h = 788 + 90 = 878\ mm$

[illegible]

use $h = 900mm$; $d = 810\ mm$

$b = 400mm$

→ Check h_{min} :

Table 9.5 →

h_{min} (S.S.b) $= \frac{L}{16} = \frac{10.000}{16}$ → $h_{min} = 625\ mm$

$h > h_{min}$ → ok.

→ Check self wt. and revise M_u

self wt. $= 0.4 * .9 * 24 = 8.64\ KN/m$

$W_u = 1.2(14.5 + 8.64) + 1.6 * 25.5$

$W_u = 68.57$ KN/m

$M_{u\,(new)} = 857\ Kn.m$

[ACI]

* If M_u is increased by 10% or more repeat the design

$\frac{857-848}{848} * 100\% = 1.1\% < 10\%$

→ * continue using $M_{u(new)} = 857$ Kn.m

$A_s = \frac{M_u}{\phi f_y jd} = \frac{857 * 10^6}{.9 * 420 * .9 * 810} = 3110 \text{ mm}^2$

* iterations :-

$A_s = 3090.3 \text{ mm}^2$

* select steel :-

7 No. 25 M ; $A_s = 3570 \text{ mm}^2$

* $b_{min} = 440$ mm > b = 400 mm

⇒ 2-layer → OK

* check $A_{s_{min}}$:-

$$\begin{cases} 964 \text{ mm}^2 \\ 1080 \text{ mm}^2 \,] \rightarrow A_{s_{min}} \end{cases}$$

$A_s = 3570 > A_{s_{min}}$ → OK

* Check ϕM_n and $\phi = 0.9$

$$a = \frac{3570 * 420}{.85 * 25 * 400} = 176.4\,mm$$

$$C = 207.5\,mm$$

$$\varepsilon_s = .003\left(\frac{810 - 207.5}{207.5}\right) = .0087 > .005$$

$$\phi M_n = .9 \times 3570 \times 420\left(810 - \frac{176.4}{2}\right)$$

$$\phi M_n = 974\ KN.m > M_u$$

* maximum Area of Tension Reinforcement.

$A_{s\,max} \rightarrow \varepsilon_s = .005$

ε_s [illegible] A_s [illegible]

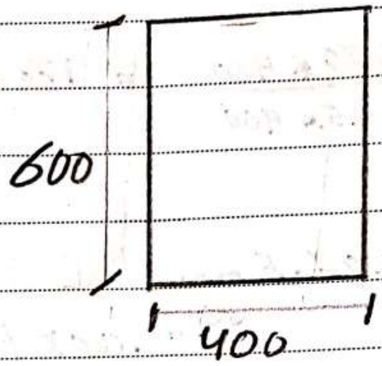
$A_s < A_{s\,max}$ $\quad \varepsilon_s \geq .005$

$$A_{s\,max} = \underbrace{0.319\,\beta_1 \frac{f_c'}{f_y}}_{\rho_{max}} bd$$

$\varepsilon_s = .005$

10/4

* Design example :→



$M_u = 720\ KN.m$

$f'_c = 28\ Mpa$

$f_y = 420\ Mpa$

* $A_s = \frac{M_u}{\phi f_y jd}$

→ assume 2-layer :→

$d = 600 - 90 = 510\ mm.$

→ $A_s = \frac{720 * 10^6}{.9 * 420 * .9 * 510} = 4150\ mm^2$

→ Check $A_{s\,max}$

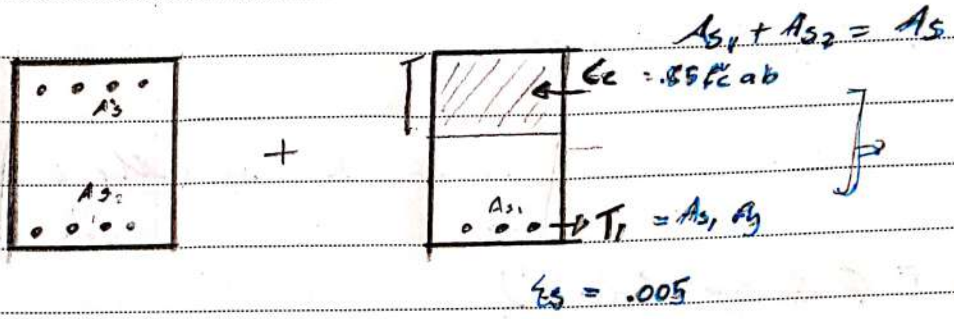
$A_{s\,max} = .319 * .85 * \frac{28}{420} * 510 * 400$

$A_{s\,max} = 3687.6\ mm^2$

$A_s > A_{s\,max} \Rightarrow \varepsilon_s < .005$

(Not Tension Controlled)

$*$ Doubly reinforcement beam. (use A'_s).



$A_{s_2} = A_{s\,max} = 3687.6\,mm^2$

$*$ Beam 2 :-

$a = \dfrac{3687.6 * 420}{.85 * 28 * 400}$ $(T_2 = C_c)$

$a = 162.7\,mm$; $c = 191.4\,mm$

$*$ $\varepsilon_s = .003 \left(\dfrac{510 - 191.4}{191.4} \right) = .005$ (check)

$\rightarrow \phi M_{n_2} = \phi A_{s_2} f_y \left(d - a/_2 \right)$

$= .9 * 3687.6 * 420 \left(510 - \dfrac{162.7}{2} \right)$

$\phi M_{n_2} = 597.5\ KN.m$

$\phi M_n = M_u = 720$

$\phi M_{n_1} + \phi M_{n_2} = 720$

$\phi M_{n_1} = 720 - 597.5 = 122.5$ KN..m (Mu beam (1))

$* \ \phi M_{n_1} = \phi A_s f_y \ (d - d')$

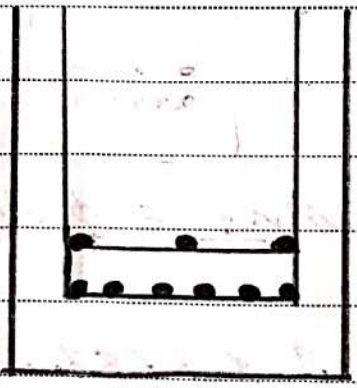
$\phi M_{n_1} = \phi A'_s \underbrace{f_y}_{\text{or } f'_s} (d - d') \rightarrow$

$\rightarrow 122.5 * 10^6 = .9 * A_{s_1} * 420 \ (510 - 65) \Rightarrow A_{s_1} = 728 \ mm^2$

$* \ A_s = A_{s_1} + A_{s_2} = 728 + 3687.6 = 4415.6 \ mm^2$ (required)

→ use 9 No. 25 M steel → $A_s = 4590 \ mm^2$

$b_{min} > b$ → 2-layers



*Design Example (cont.)

$A_s = 4150 \, mm^2$

$A_{s\,max} = 3687.6 \, mm^2$

$A_{s_2} = A_{s\,max}$

$a = 162.7 \, mm$

$\phi M_{n_2} = 597.5 \, KN.m$

$\phi M_{n_1} = 122.5 \, KN.m$

⇒

$\phi M_{n_1} = \phi A_{s_1} f_y (d-d')$

$\phi M_{n_2} = \phi A_s' \underbrace{f_s'}_{} (d-d')$

↳ f_s' or f_y

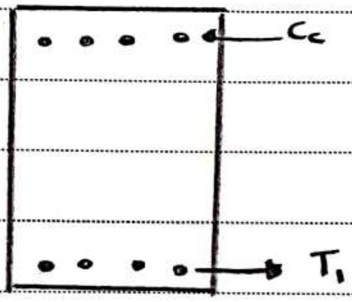
→ $A_{s_1} = 728 \, mm^2$

$A_s = 4415.6 \, mm^2$

"9 No.25 M; $A_s = 4590 \, mm^2$"

$$\varepsilon_s' = .003 \left(\frac{191.4 - 65}{191.4}\right)$$

$$= .00198 < \varepsilon_y$$



$f_s' = 200.000 * .00198$

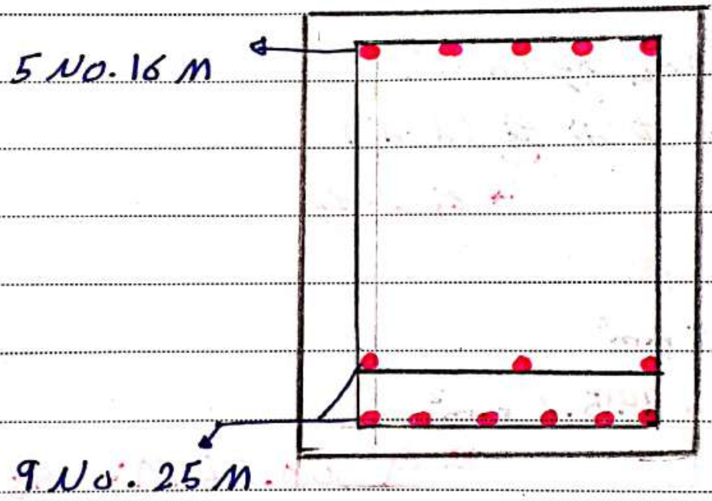
$* f_s' = 396 \, Mpa$

$A_{s_1} f_y = A'_s f_y$

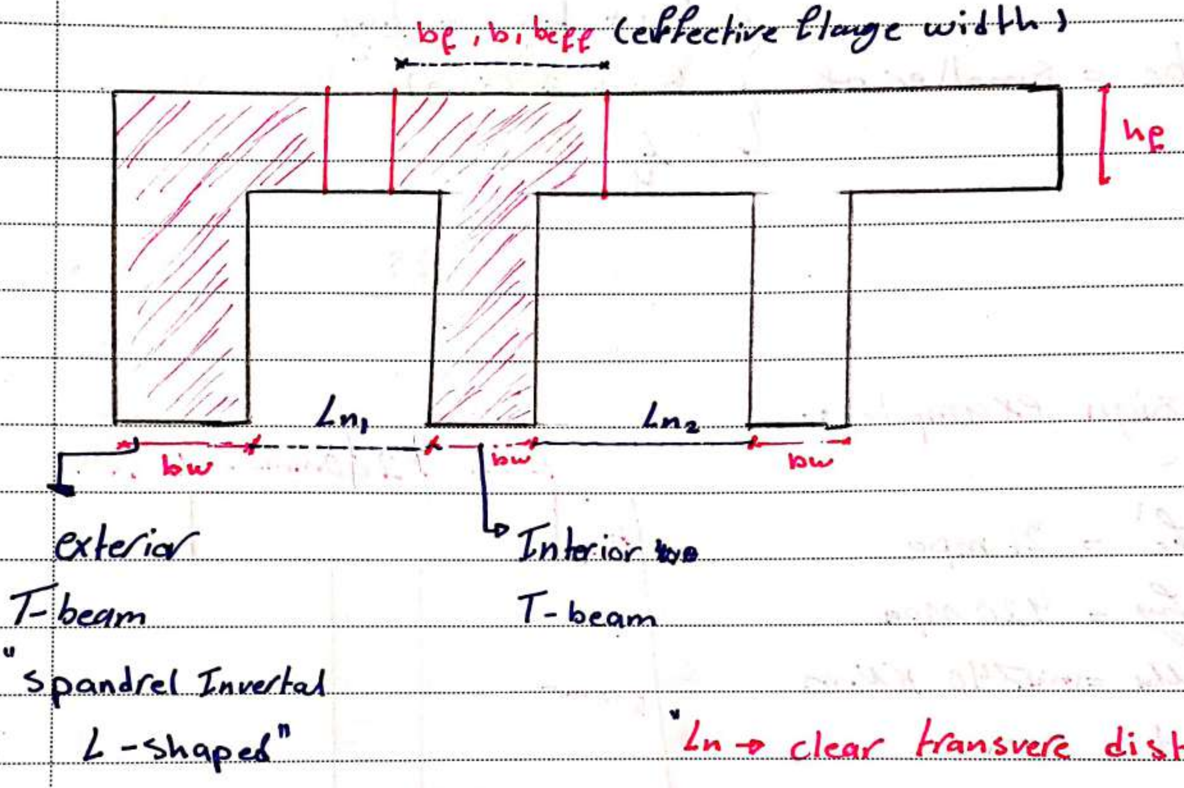
$A_{s_1} = 4590 - 3687.6 = 902.4\ mm^2$

$\rightarrow 902.4 * 420 = A'_s * 396 \rightarrow \underbrace{A'_s}_{\text{required}} = 957 mm^2$

$*$ Use 5 No. 16M ; $A'_s = 995\ mm^2$



* Design of T - beams.



"Ln → clear transvere distance"

⇒ Exterior T- beam".

$$b_e = \text{smaller of} \begin{cases} b_w + \frac{L_{n_1}}{2} \\ b_w + 6h_f \\ b_w + \frac{L}{12} \end{cases}$$

L → Span length of the beam.

⇒ Interior T-Beam".

$$b_e = \text{Smaller of} \begin{cases} b_w + \frac{L_{n1}}{2} + \frac{L_{n2}}{2} \\ b_w + 2\,(8h_f) \\ \frac{L}{4} \end{cases}$$

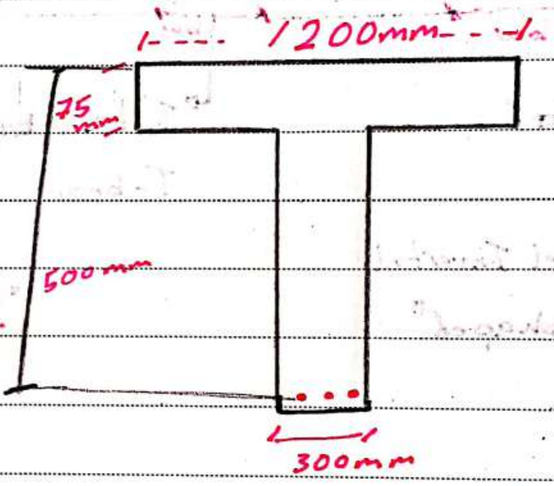
* Design example :-

$f_c' = 21$ mpa

$f_y = 420$ Mpa

$M_u = (+ve)\ 740$ KN.m

d = 500 mm



$$* \overset{??}{A_s} = \frac{M_u}{\phi f_y j d}$$

- * Flange in Tension → Design → rectangular (j = 0.9) "Narrow comp. Area"
- * Flange in Compression → j = .95 (wide compression area)

NO.

→ $A_s = \frac{M_u}{\phi f_y j d}$

$= \frac{740 * 10^6}{.9 * 420 * .95 * 500} = 4121 \text{ mm}^2$

* Use 9 No. 25 M ; $A_s = 4590 \text{ mm}^2$

→ check $A_{s\,min} = \begin{cases} 500 \text{ mm}^2 \;] \to A_{s\,min} \\ 400 \text{ mm}^2 \end{cases}$ ok

* $T = C_c$ $a \leq h_f$

$4590 * 420 = .85 * 21 * a * 1200$

$a = 90 \text{ mm} > h_f$ T-beam

→ $T_f = C_{cf}$

$A_{sf} * 420 = .85 * 21 * (1200 - 300) * 75$

$A_{sf} = 2869 \text{ mm}^2$

→ $T_w = C_{cw}$ $(A_{sw} = 4590 - 2869 \to 1721 \text{ mm}^2)$

$1721 * 420 = .85 * 21 * a * 300$

$a = 135 \text{ mm}$; $C = 158.8 \text{ mm}$

NO.

$\varepsilon_s = .003 \left(\frac{500 - 158.8}{158.8} \right) = .0064$ $> .005$ (Tension controlled) $\Downarrow \phi = .9$

$\phi M_{n_f} = .9 * 2869 * 420 \left(500 - \frac{75}{2} \right) = 501.6$ KN.m

$\phi M_{n_w} = .9 * 1721 * 400 \left(500 - \frac{135}{2} \right) = 281.4$ KN.m

$\phi M_n = \phi M_{nf} + \phi M_{nw} \rightarrow 783$ KN.m $> M_u$

⇒ Check As required based on Computed value of $\underline{a}$.

$\phi M_n = M_u$

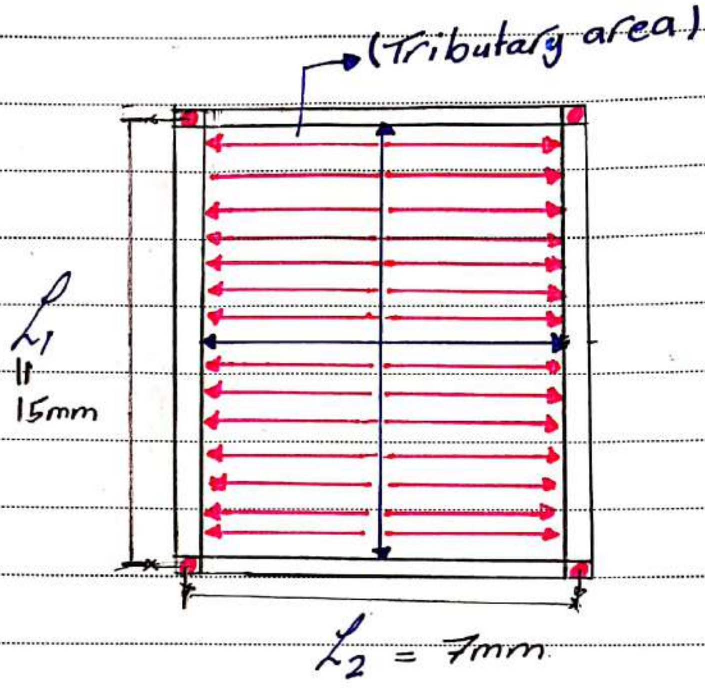
$501.6 + \phi M_{n_w} = 740$

$\phi M_{n_w} = 238.4$ KN.m $= M_{u_w}$

$238.4 * 10^6 = 0.9 * A_{sw} * 420 \left(500 - \frac{135}{2} \right)$

$A_{sw} = 1458 \, mm^2$ (required) $< 1721 \, mm^2$

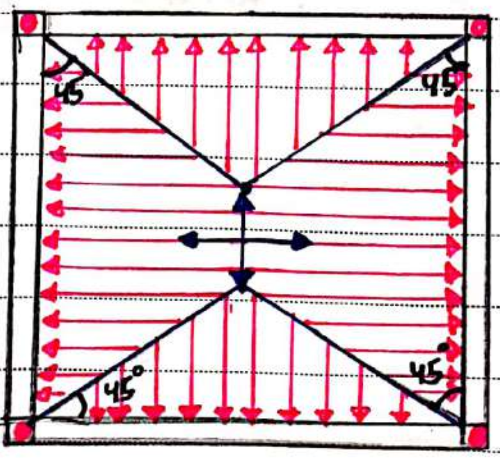
* One way solids slabs



$\frac{L_1}{L_2} \geq 2$ "one way"

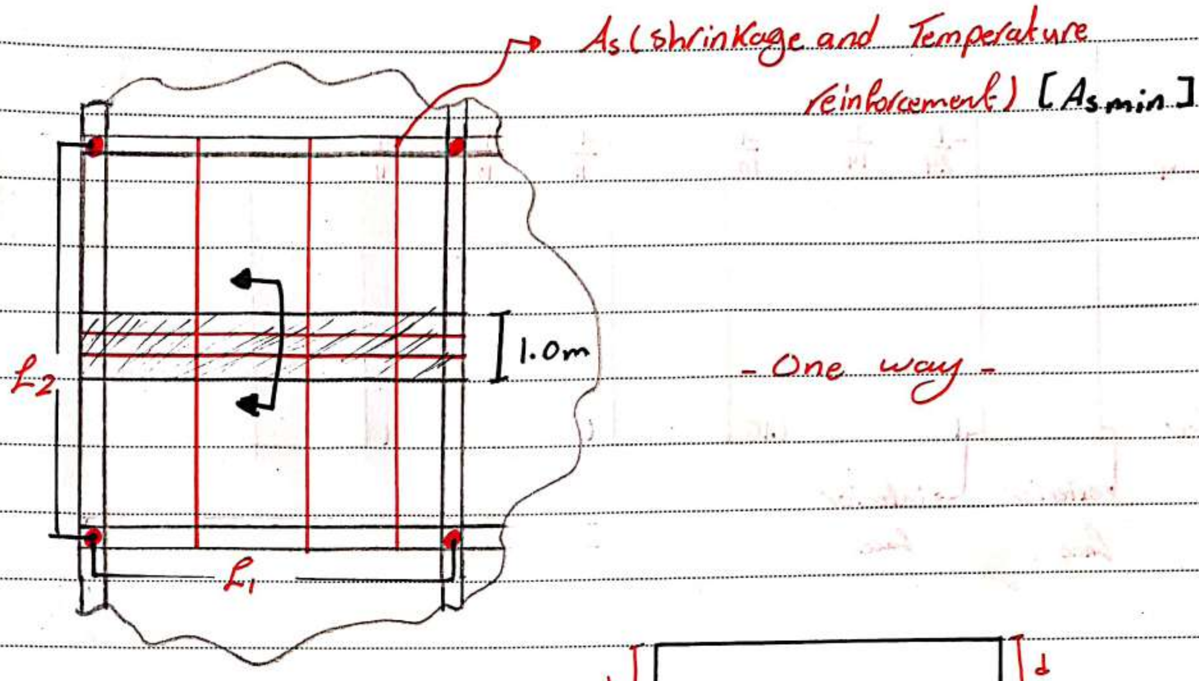
* $\frac{\text{Longer dim}}{\text{Shorter dim}} \geq 2$ (one-way)

< 2 (Two-way)

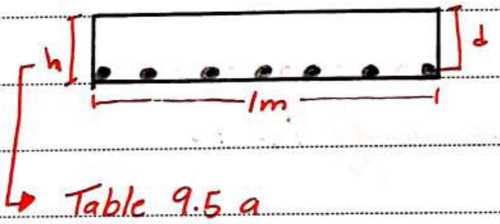


$\frac{L_2}{L_1} < 2$

Two way slab



- One way -

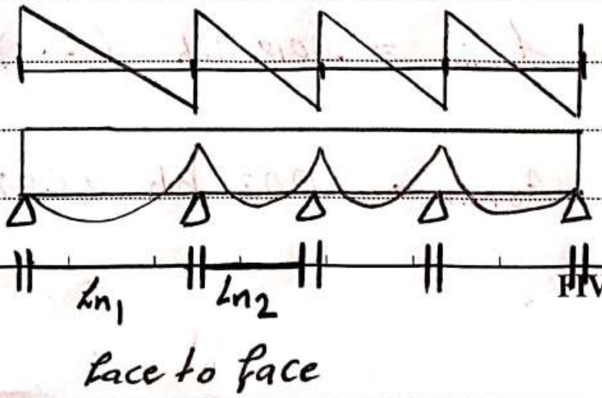


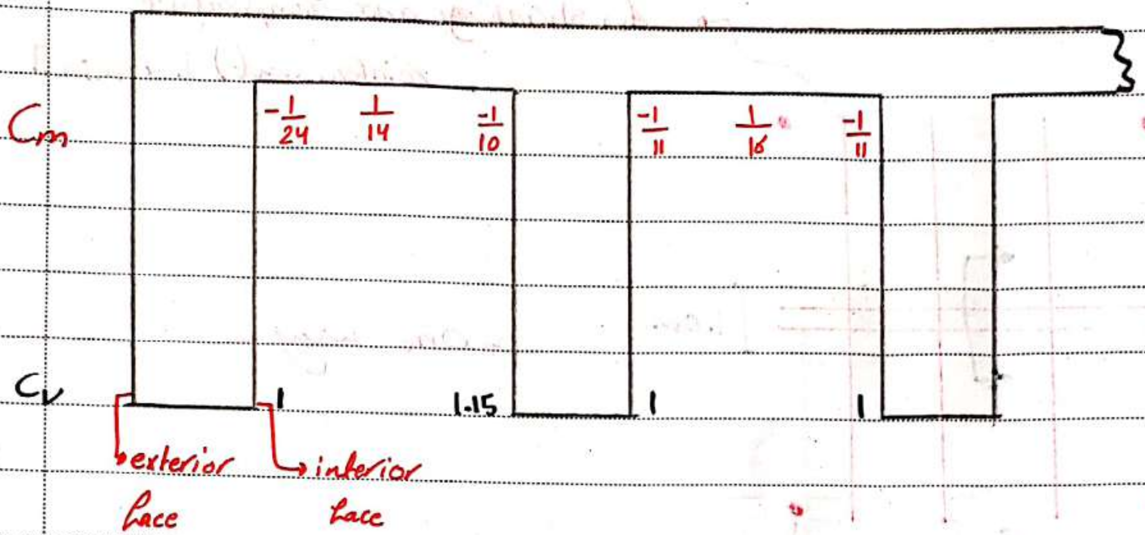
* $A_s = \frac{M_u}{\underset{.9}{\phi} f_y \underset{.95}{j} d}$

* min cover = 20 mm
(Normal expousre)

* ACI - Moment and Shear Coefficient Method"

* $M_u = C_m (w_u l_n^2)$
* $V_u = C_v \left(\frac{w_u l_n}{2}\right)$





* Use only if :-

→ different in Length = 20%

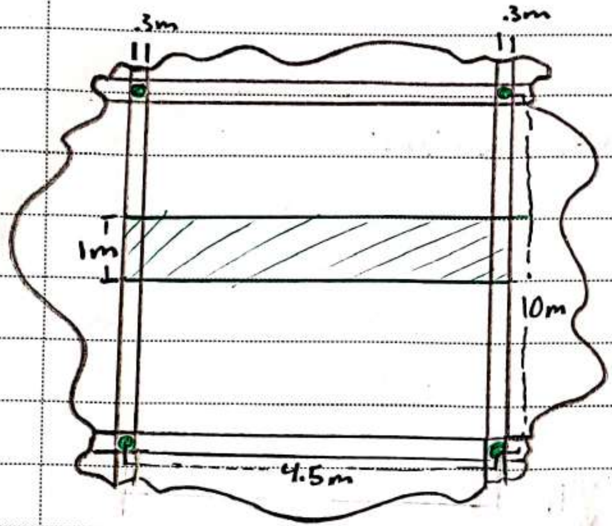
→ LL ≤ 3DL

→ prismatic

* Min Amount of Tension reinforcement

$A_{s\,min}$ = .0018 bh (G60)

$A_{s\,min}$ = .002 bh (G40 or G50)



* $f'_c = 28$ Mpa

$f_y = 414$ Mpa

$W_L = 4\ KN/m^2$

$W_D = 3 KN/m^2$ (excluding self wt)

⇒

$\frac{10}{4.5} = 2.22 > 2$ → one way

* Thickness → h

$$h_{min} = \frac{L}{28} = \frac{4500}{28} = 160\ mm$$

" Use $h = 180\ mm$ "

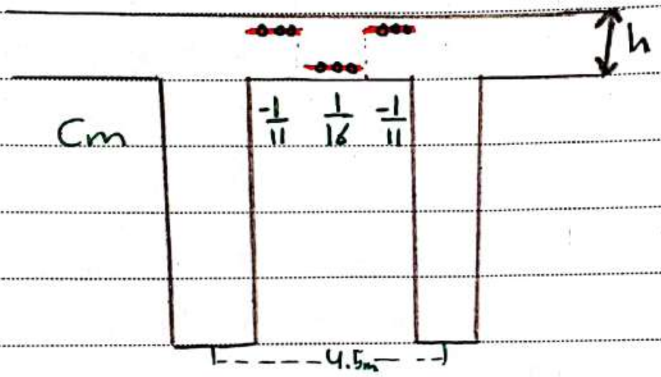
NO.

* M_u

self wt $= 24 * .18 = 4.32\ KN/m^2$

$W_u = 1.2(3 + 4.32) + 1.6 * 4$

$= 15.18\ KN/m^2$

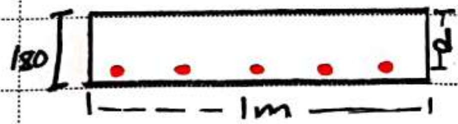


→ $M_u = C_m (W_u\ l_n^2)$

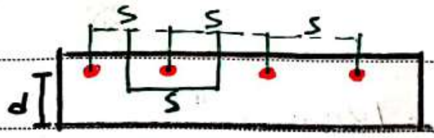
$l_n = 4.5 - 0.3 = 4.2\ m$

→ $M_u(-ve) = \frac{1}{11} * 15.18 * 4.2^2 = 24.34$

→ $M_u(+ve) = \frac{1}{16} * 15.18 * 4.2^2 = 16.74\ Kn.m$



+Ve M



-Ve M

→ $A_s = \frac{M_u}{\phi f_y jd}$ (Use No.16M steel)

⇒ $d = 180 - 20 - \frac{16}{2} = 152\,mm$

$M_u\,(-ve) = 24.34\ KN.m$

⇒ $As = \frac{24.34 * 10^6}{.9 * 414 * .95 * 152} = 452.4\ mm^2/m$

→ $As_{min} = .0018 * 1000 * 180 = 324\ mm^2/m$

$A_s > As_{min}$

→ $a = \frac{452.4 * 414}{.85 * 28 * 1000} = 7.87$

* $A_s = 441.2\ mm^2$ → $a = 7.67\ mm$ → $A_s = 440.9\,mm^2/m$

→ $\varepsilon_s = 0.0477 \gg .005$

→ $s = \frac{1000\ A_b}{A_s}$] → Cross section area of one bar 1 No.16 M

↳ $A_b = 199\ mm^2$

$s = \frac{1000 * 199}{440.9} = 451\ mm$

→ Use 450 mm

S_{max} = smaller of $\begin{cases} 450\,mm \\ 3h = 3 * 180 = 510\,mm \end{cases}$

→ S_{max} = 450 mm

[Use S = 450 mm]

* M_u (+ve) →

$$A_s = \frac{16.74 * 10^6}{.9 * 414 * .95 * 152} = 311\ mm^2/m$$

$A_s < A_{s\,min}$ → Use $A_{s\,min}$ ∴ $A_s = 324\ mm^2/m$

$$* \ S = 1000 * \frac{199}{324} = 614.2\ mm$$

$S > S_{max}$ → Use S_{max}

⇒ S = 450 mm

→ Shrinkage and Temprelure reinforcement is required perpendicular to the span of the slab (ACI - Code).

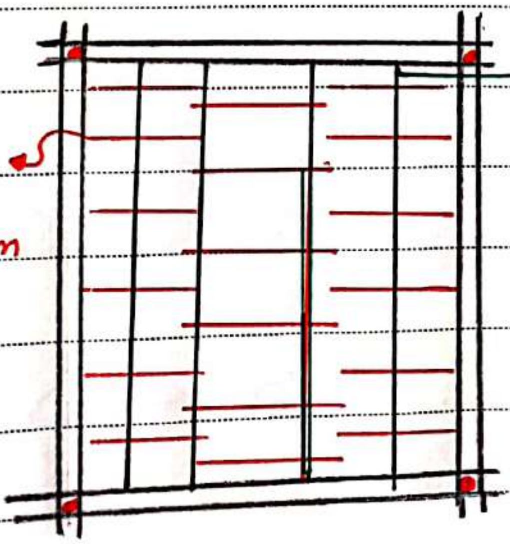
* $A_{s\,min} = 324\ mm^2/m$

* $S = \frac{1000}{324} A_b = 614$

* $S_{max} =$ smaller of $\begin{cases} 450mm \\ 5h \rightarrow 5*180 = 900mm \end{cases}$

$S_{max} = 450mm$

[redacted] Use → $S = 450mm$



1No.16M @ 450 mm

1No.16M @ 450mm

"Don't Let anyone, ever, make you feel
Like you don't deserve what you want."

" CiviLittee ♡"