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Reinforced Concrete Design CV3201. 12/13 S1

Q1. $b = 350mm$, $h = 550mm$, $\delta = 0.8$. (Given)

$M_{Ed} = 300 kNm$.

=> Interior Support

=> Hagging Moment

Concrete C25, 500MPa Steel bars., Cover = 45mm, stirrup ϕ = 10mm (Given)

- From Table:

20% Redistribution.

$x'_{bal}/d = 0.288$ (From Table 4).

$z_{bal}/d = 0.869$.

$K'_{bal} = 0.116$.

$d'/d = 0.109$

Choosing ϕ of 25mm (H25 bars).

$\therefore d = 550 - \text{cover} - \text{link} - \frac{1}{2}\phi$ (Main Reinforcement)

$= 550 - 45 - 10 - \frac{1}{2}\times 25$

$= 482.5$ mm.

$\because K = \dfrac{M_{Ed}}{f_{ck} b d^2} = \dfrac{300\times10^6 \text{ Nm}}{25\times350\times482.5^2}$

$= 0.1472$

$\because K > K_{bal}$, Compression steel bars are required.

Use H25 bars as compression steel bars.

$d' = \text{cover} + \text{link} + \frac{1}{2}\phi$

$= 45 + 10 + \frac{1}{2}\times25$

$= 67.5$ mm

$\dfrac{d'}{d} = \dfrac{67.5}{482.5} = 0.1389 > \dfrac{d'}{d} = 0.109$

$\therefore$ Compression steels Not yield.

- Area of the Compression Steel.

$M'_{Ed} = M_{Ed} - K_{bal} f_{ck} b d^2$

$= 300\times10^6 - 0.116\times25\times350\times482.5^2$

$= 63.70\times10^6$ Nmm.

$\because x = 0.288d$

$= 0.288\times482.5 = 138.96$ mm

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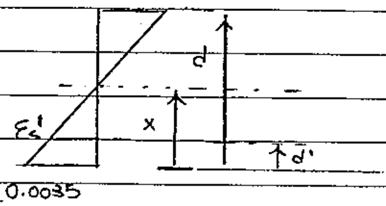
$$\frac{\varepsilon_s'}{0.0035} = \frac{x-d'}{x}$$

$$\therefore \varepsilon_s' = \frac{x-d'}{x}(0.0035)$$



$$\therefore f_{sc}' = \varepsilon_s' \times 200\,GPa$$

$$= \left(1-\frac{d'}{x}\right) \times 0.0035 \times 200 \times 10^3\ N/mm^2$$

$$= \left[1 - \frac{67.5}{138.95}\right] \times 700\,N/mm^2$$

$$= 359.95\ N/mm^2$$

$$\therefore A_s' = \frac{M'_{Ed}}{f_{sc}'(d-d')}$$

$$= \frac{63.70 \times 10^6}{359.95 \times (482.5 - 67.5)}$$

$$= 426.4318\ mm^2$$

$\therefore A_{s\,provided} = 982\ mm^2$ (2H25mm bars).

- Tension Steel bars:

$$\because Z = 0.869\,d = 0.869 \times 482.5 = 419.2925\,mm$$

$$A_s = \frac{K_{bal} f_{ck} b d^2}{0.87 f_{yk} Z} + A_s' \times \frac{f_{sc}'}{0.87 f_{yk}}$$

$$= \frac{0.116 \times 25 \times 350 \times 482.5^2}{0.87 \times 500 \times 419.2925} + 426.4318 \times \frac{359.95}{0.87 \times 500}$$

$$= 1295.55 + 352.86$$

$$= 1648.4100\ mm^2$$

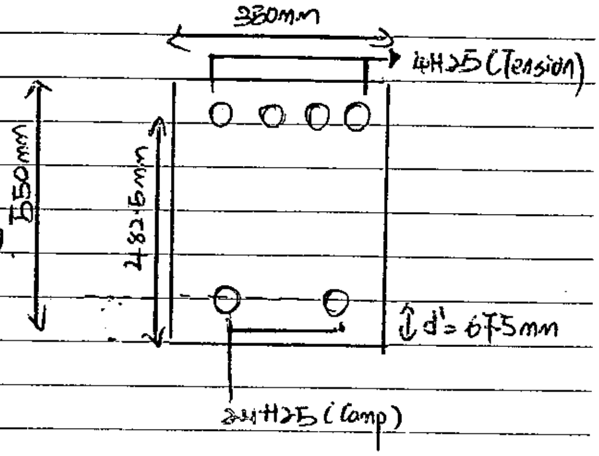
$\therefore A_{s\,provided} \Rightarrow$ 4H25 bar

$= 1964\ mm^2$.

- Minimum percentage of Reinforcement.

For $f_{ck} = 25MPa$, $A_{s\,min} = 0.13\%$

$$A_{s\,prov} = \frac{1964+982}{350 \times 482.5} \times 100\% = 1.74\% > 0.13\%\ (Okay).$$



- Reinforcement Details

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Q2. $G_k = 40\,kN/m$ $L = 6m$ $h = 500mm$ l_w = Support(width) = 300mm. (Given)

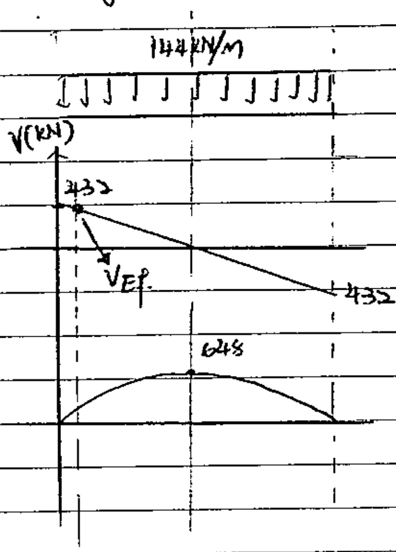
$Q_k = 64\,kN/m$ $b = 300mm$ $d = 440mm$ $f_{ck} = 25MPa$, $f_{yk} = 500MPa$

$\therefore n = 1.35G_k + 1.5Q_k$

$= 1.35 \times 40 + 1.5 \times 60$

$= 144\,kN/m.$

Simply Supported beam.



$V_{max} = \frac{n \times L}{2}$ $M_{max} = \frac{n \times l^2}{8}$

$= 144 \times 6 \times 0.5$ $= 648\,kNm$

$= 432\,kN$

$V_{Ef} = V_{max} - n \times l_w \times 0.5$

$= 432 - 144 \times 300 \times 0.5 \times 1000^{-1}$

$= 432 - 21.6$

$= 410.4\,kN.$

For $f_{ck} = 25MPa$.

$V_{Rd,max(22)} = 0.9\,\tau_{Rd,max(22)}\,bwd$

$= 0.9 \times 3.10 \times 0.3 \times 0.44 \times 1000\,kN$

$= 368.28\,kN > V_{Ef}$

$V_{Rd,max(45)} = 0.9\,\tau_{Rd,max(45)}\,bwd$

$= 0.9 \times 4.50 \times 0.3 \times 0.44 \times 1000\,kN$

$= 534.6\,kN. < V_{Ef}$

$$\theta = 0.5\sin^{-1}\left[\frac{V_{Ef}}{V_{Rd,max(45)}}\right] \leq 45°$$

$$= 0.5\sin^{-1}\left[\frac{410.4}{534.6}\right]$$

$= 25.0788°$

$\simeq 25.08°$

1 d from the support face. $d = 440mm$

$V_{1d} = V_{Ef} - n \times d$

$= 410.4 - 144 \times 0.44$

$= 347.04\,kN.$

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$V_{Ed}(1d) = 347.04\,kN$, $\theta = 25.08$, $d = 440mm$

$$\therefore \frac{A_{sw}}{s} = \frac{V_{Ed}}{0.78 d f_{yk} \cot\theta}$$

$$= \frac{347 \times 10^3 N}{0.78 \times 0.44 \times 500 \times \cot 25.08 \times 1000}$$

$$= 0.946$$

$$\therefore \frac{A_{w}}{s}_{provided} = 1.004 \;(H12, S225).$$

$S_{max} \leq 0.75d = 0.75 \times 440 = 330mm$ (okay!)

Minimm Stirrup at Zone III.

$$\frac{A_{sw}}{S}_{min} = \frac{0.08 f_{ck}^{0.5} b_w}{f_{yk}}$$

$$= \frac{0.08 \times 25^{0.5} \times 300}{500}$$

$$= 0.24$$

$$\therefore \frac{A_{sw}}{s}_{provided} = 0.753 \;(H12\; S300)$$

$S_{max} \leq 0.75d = 330mm$ (okay).

Calculation of X_2.

$$V_{(x_2)} = \frac{A_{sw}}{s}_{provided} \times 0.78d \times f_{yk} \cot\theta.$$

$$= 0.753 \times 0.78 \times 440 \times 500 \times \cot 25.08^\circ \times 10^{-3}\,kN$$

$$= 276.09\,kN.$$

$$\therefore X_2 = \frac{V_{Ef} - V_{(x_2)}}{\lambda} \qquad \lambda = 144\,kN/m$$

$$= \frac{410.4 - 276.09}{144} \times 1000\,mm$$

$$= 932.70\,mm.$$

Additional longitudinal Reinforcement

$a_2 = 1.125d$ $\qquad \Delta F_{td} = 0.5\, V_E \cot\theta.$

$= 1.125 \times 440\,mm$

$= 495mm$

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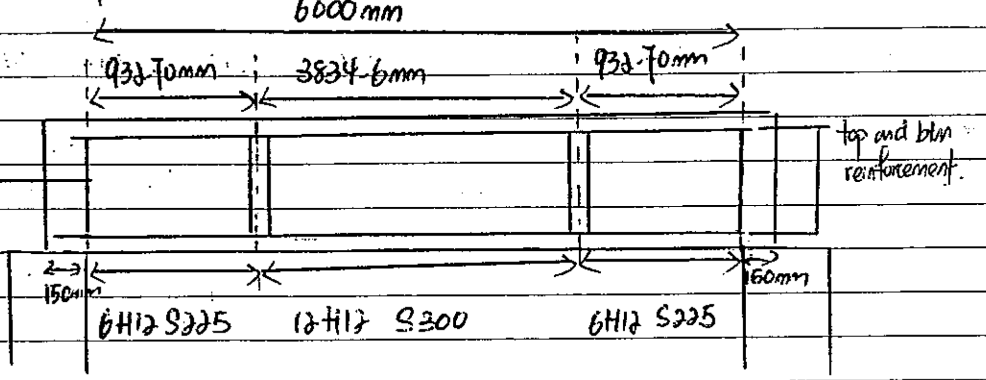
Reinforcement Details.



- Simply supported beam
  → Both direction has the same configuration.

- Midspan length = 6000 mm − 300mm (Support) − 2x 932.70 (Zone I & II).
  l_m = 3834.6mm.

- # of links in Zone I and II.

  ∴ # of link = $\frac{X_2}{S} + 1$

  $= \frac{932.70}{225} + 1$

  $= 5.145 \simeq 6.$

# of links in Zone III

∴ # of link = $\frac{l_m}{S} - 1$

$= \frac{3834.6}{300} - 1$

$= 11.782$

$\simeq 12.$

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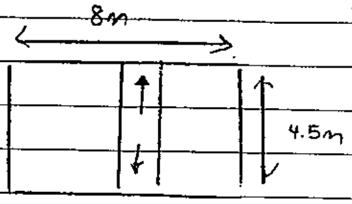
Q3 One way spanning slab (Simply Supported)

$\therefore G_k = 1\,kN/m^2 +$ Self weight $\quad Q_k = 3\,kN/m^2$, Cover = 20mm, $f_{ck} = 32\,N/mm^2$, $f_y = 500\,MPa$

Based on Table 5.8.

- We choose $l/d = 30$.
- We design for $l = 4500\,mm$



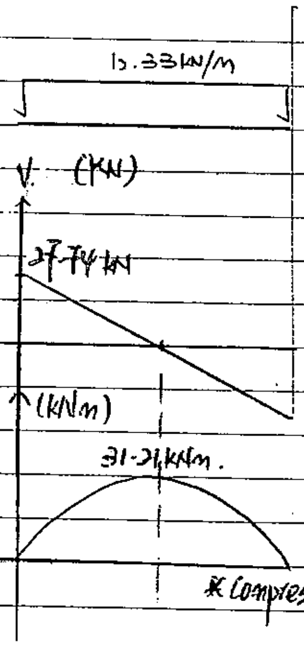
$\therefore \frac{L}{d} = 30$

b = 1000mm
l = 4500mm.

$d = 4500 \div 30$
$= 150\,mm$.

$\therefore$ We choose $h = 200\,mm$.

$\therefore d$ = height − cover − $\frac{1}{2}\phi$ bars.
$= 200 - 20 - \frac{1}{2}\times 13$
$= 173.5\,mm$.



$G_k = 1\,kN/m^2 + 24\,kN/m^3 \times 0.2\,m$.
$= 5.8\,kN/m^2$

$\therefore n = 1.35G_k + 1.5Q_k$
$= 1.35\times 5.8 + 1.5\times 3$
$= 12.33\,kN/m^2$.

$\because b = 1000\,mm = 1\,m$.
$\therefore W = 12.33\,kN/m$.

$\therefore V_{max} = \frac{Wl}{2} = \frac{12.33\times 4.5}{2} = 27.7425\,kN \triangleq 27.74\,kN$

* Compression side.

$M_{max} = \frac{Wl^2}{8} = \frac{12.33\times 4.5^2}{8} = 31.2103125\,kNm \triangleq 31.21\,kNm$

Area of Main Reinforcement

$\because K = \frac{M_{Ed}}{f_{ck}bd^2} = \frac{31.21\times 10^6}{32\times 1000\times 173.5^2} = 0.03239 < 0.167$ (okay).

$\cancel{z = d\left[0.5 + \sqrt{0.25 - \frac{K}{1.134}}\right] = d\left[0.5 + \sqrt{0.25 - \frac{0.03239}{1.134}}\right] = 0.97d \quad (< 0.95d)}$

$\therefore z = 0.95d$
$= 0.95\times 173.5\,mm$
$= 164.825\,mm$

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$\therefore A_s = \frac{M_{Ed}}{0.87 f_{yk} z} = \frac{31.21 \times 10^6}{0.87 \times 500 \times 164.825} mm^2$

$= 435.2927 mm^2.$

$A_{s,min} = \max\left[0.26 \frac{f_{ctm}}{f_{yk}} bd, 0.0013bd\right]$

$= \max\left[0.26 \times \frac{3}{500} \times 1000 \times 173.5, 0.0013 \times 1000 \times 173.5\right]$

$= \max\left[270.66 mm^2, 225.55 mm^2\right]$

$= 270.66 mm^2.$

$A_{s,provided} = 531 mm^2 > A_{s,min}$ (okay!).
$\Rightarrow$ H13 S 225 mm.

$h = 200mm$
$S_{max} = 2h \leq 250mm$
$\therefore S_{max} \leq 250mm$ (okay)

Shear Cheak.

$v_{Ed} = \frac{V_{Ed}}{bd} = \frac{27.74 \times 1000}{1000 \times 173.5} N/mm^2$

$= 0.15988$

$v_{Rd,c} = \frac{0.18}{\gamma_c} k (\rho_1 f_{ck})^{1/3}$

$= \frac{0.18}{1.5} \times 2 \times (0.30605 \times 32)^{1/3}$

$= 0.51348..$

$\rho_1 = \frac{A_{s,prov}}{bd} \times 100\%$

$= \frac{531}{1000 \times 173.5} \times 100\%$

$= 0.30605\%$

$k = \left[1 + \sqrt{\frac{200}{d}}\right] \leq 2.$

$= \left[1 + \sqrt{\frac{200}{173.5}}\right] \leq 2$

$= 2.0736 \leq 2$

$\therefore k = 2.$

$v_{Rd,min} = 0.035 k^{3/2} f_{ck}^{1/2}$
$= 0.035 \times 2^{3/2} \times 32^{1/2}$
$= 0.56.$

$\therefore v_{Ed} < v_{Rd}$ (okay)
$\therefore$ shear reinforcement is Not required.

Transverse Reinforcement.

$A_s = 0.2 A_{s,req}$
$= 0.2 \times 435.2927 mm^2$
$= 87.055 mm^2$

$\because A_{s,prov} > A_{s,min}$ $A_{s,min} = 270.66 mm^2.$

$\therefore A_{s,prov} = 442 mm^2$ (H13-S300) $S_{max} = 3h \leq 400mm$

$\therefore S < S_{max}$ (okay)

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Deflection Check.

$$\frac{As_{req}}{bd} = \frac{270.66}{1000 \times 173.5} \times 100\% = 0.166\% < 0.35\% \text{ (Table 5.8)}$$

$\therefore$ l/d basic = 30 (Simply Supported Slab).

$$l/d_{allowable} = 30 \times \frac{As_{prov}}{As_{req}}$$

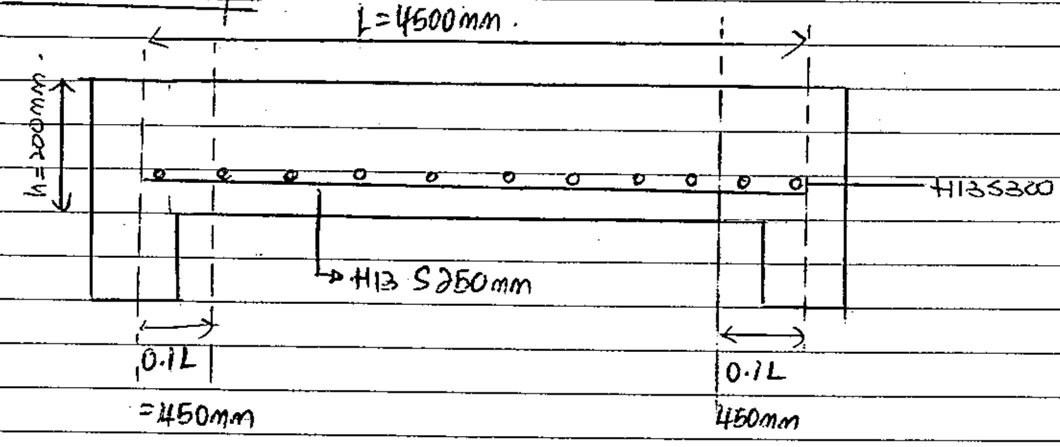
$$= 30 \times \frac{531}{270.66}$$

$$= 58.85$$

$$\therefore l/d_{actual} = \frac{4500}{173.5} = 25.93 < l/d_{allowable}.$$

$\therefore$ Deflection check (Okay).

Reinforcement Details.



• Simply Supported One Way Slab.

Q3 $C_{NOM} = C_{MIN} + \Delta C_{dev}$.

b) C_{NOM}: Nominal Cover to the center of main Reinforcement bar.

C_{MIN}: Minimum Cover

ΔC_{dev}: Adequate in design for deviations from minimum cover.

Nominal Cover is so important as it can permit safe transmission of bond forces, protection of the steel against corrosion and to permit steel to perform their function during fire situation. It can also provide adequate fire resistance since concrete is good at fire resistance.

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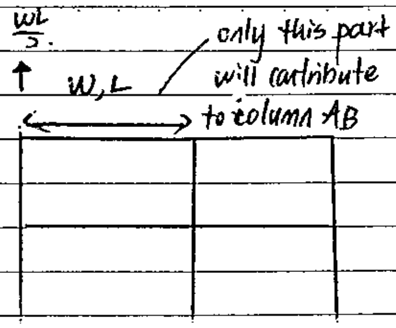
Q4. Spacing between Frame = 5.5m.

a)



loading (Roof).

$n = 1.35G_k + 1.5Q_k$

$= 1.35 \times 5 + 1.5 \times 1$

$= 8.25\ kN/m^2$.

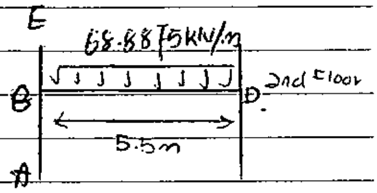
$\therefore W = 8.25 \times 5.5$ (Spacing of Frame)

$= 45.375\ kN/m$.

$P_{roof} = \frac{wl}{2}$ $\quad l = 5.5m$

$= 0.5 \times 45.375 \times 5.5$

$= 124.78125\ kN$.



loading (Floor)

$n = 1.35G_k + 1.5Q_k$

$= 1.35 \times 6.5 + 1.5 \times 2.5$

$= 12.525\ kN/m^2$

$W = 12.525 \times 5.5$

$= 68.8875\ kN/m$.

$P_{Floor} = \frac{wl}{2}$ $\quad l = 5.5m$

$= 0.5 \times 68.8875 \times 5.5$

$= 189.44\ kN$

Moment $= M_{BD} = \frac{1}{12}wl^2$

$= \frac{1}{12} \times 68.8875 \times 5.5^2$

$= 173.6539\ kNm$.

$\frac{K_{beam}}{K_{column}} = \frac{2}{1}$

$\therefore K_{beam} = 2K_{column}$

$= 2$.

$\therefore M_{BA} = \frac{K_{AB}}{\Sigma K} \times M_{BD}$

$= \frac{1}{3} \times 173.6539$

$= 57.88\ kNm$

let $K_{column} = 1$

$K_{beam} = 2$.

$K_{BE} = 1$

$K_{BA} = 1$

$K_{BD} = 0.5 \times 2$ (Half Stiffness)

$= 1$.

Self Weight of Column.

$l_{Total} = 3.75 \times 6$

$= 22.5m$.

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

$b = 0.3m,\ h = 0.35m$

$\therefore W = 1.35 \times 22.5 \times 0.3 \times 0.35 \times 24$

$= 76.545\ kN$ (Factored)

$\therefore P_{axial} = $ Roof $+ 5 \times$ Floor $+$ Weight

$= 124.78125 + 189.44 \times 5 + 76.545$

$= 1148.5265\ kN$.

$M = Ne$

$= 1148.5265 \times 0.02$

$= 22.97053\ kNm$

$< M_{BA}$ (57.88 kNm)

$e = \max\left[\frac{h}{30}, 20\right]mm$

$= \max(11.67, 20)$

$= 20mm$

Ans:

$\therefore P_{axial} = 1148.5265\ kN$

$M_{BA} = 57.88\ kNm$

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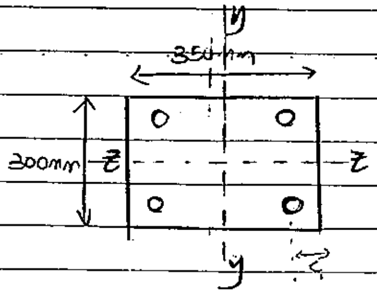
b) $M_{yy} = 57.88\,kNm$ $\quad N_{Ed} = 1148.5265\,kN$

$M_{zz} = 50\,kNm.$ $\quad f_{ck} = 40\,MPa$



$h = 350mm \quad b = 300mm$

$\therefore \frac{d}{h} = 0.86$

$\therefore d = 0.85 \times 350$

$= 297.5mm.$

$\therefore \quad h' = 297.5mm.$

$\therefore C = 350 - 297.5$

$= 52.5$

$\therefore b' = b - 52.5$

$= 247.5mm.$

$$\frac{M_{Edy}}{h'} = \frac{57.88 \times 10^3}{297.5} = 194.55$$

$$\frac{M_{Edz}}{b'} = \frac{50 \times 10^3}{247.5} = 202.02$$

$\therefore \frac{M_{Edz}}{b'} > \frac{M_{Edy}}{h'}$ (Can combine them into bending about Minor Axis)

$$\therefore M_{Edz}' = M_{Edz} + \beta\left(\frac{b'}{h'}\right) M_{Edy}.$$

$$= 50 + 0.72 \times \frac{247.5}{297.5} \times 57.88$$

$$= 84.6696$$

$M_{Edz}' \approx 84.67\,kNm.$

$$\frac{N_{Ed}}{bhf_{ck}} = \frac{1148.5265 \times 10^3}{300 \times 350 \times 40}$$

$$= 0.2734.$$

$\therefore$ Choose $\beta = 0.72$ (Table coefficient β for biaxial bending)

According to BS 8110

y axis: $\frac{N}{bh} = \frac{1148.5265 \times 10^3}{300 \times 350} = 10.933\,N/mm^2$

X axis: $\frac{M}{bh^2} = \frac{84.67 \times 10^6}{300 \times 350^2} = 2.3039\,N/mm^2$

$\therefore \frac{100 A_{sc}}{bh} = 0.4.$

$\therefore A_{sc} = \frac{0.4 \times 300 \times 350}{100} = 420mm^2$

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$As_{prov} = 805mm^2$

$\Rightarrow$ 4H16 bars.

$As_{min} = [0.002bh]$

$= 0.002 \times 300 \times 350$

$= 210mm^2$ (okay).

Ans: $As_{prov} = 805mm^2$.

Reinforcement Details.