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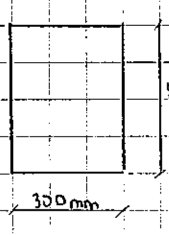
AY 11-12 S1

SUBJECT CV3201 RC Design A1

1a



$M = 285\ kNm$

M after redistribution $= 1.075 \times 285 = 306.375\ kNm$

$\delta = \frac{306.375}{285} = 1.075 > 1$ (Design based on the moment before redistribution)

Using T32 steels, $d = 500 - 35 - 12 - \frac{32}{2} = 437\ mm$

$K = \frac{M}{bd^2 f_{ck}} = \frac{285 \times 10^6}{300(437)^2 \cdot 35} = 0.142 < 0.167$ (Singly reinforced)

$z = d\left[0.5 + \sqrt{0.25 - \frac{K}{1.134}}\right] = 437\left[0.5 + \sqrt{0.25 - \frac{0.142}{1.134}}\right] = 372.9\ mm$

$z/d = 0.85 < 0.95$

$A_s = \frac{M}{0.87 f_{yk} \cdot z} = \frac{285 \times 10^6}{0.87 \times 500 \times 372.9} = 1{,}757\ mm^2$ (Provide 3H32, $A_s = 2413\ mm^2$)

b

$M_{hogging} = 344\ kNm$

M after redistribution $= 0.85 \times 344 = 292.4\ kNm$

$\delta = \frac{292.4}{344} = 0.85 < 1$

$K = \frac{M}{bd^2 f_{ck}} = \frac{292.4 \times 10^6}{300(437)^2\ 35} = 0.146 > 0.129$ (Doubly reinforced)

$d' = 35 + 12 + \frac{32}{2} = 63$

$d'/d = 0.144 > 0.125$ (Compression steel has not yielded, $f_{sc} < 0.87 f_{yk}$

$X_{bal} = 0.328d = 143.3\ mm$ $z = 0.869d = 379.8\ mm$

$\varepsilon_{sc} = \frac{0.0035(143.3 - 63)}{143.3} = 0.00196$

$f_{sc} = E_s \cdot \varepsilon_{sc} = 200 \times 10^3 \times 0.00196 = 392\ N/mm^2$

Compression steel, $A_s' = \frac{(0.146 - 0.129) \times 35 \times 300 \times 437^2}{392(437 - 63)} = 233\ mm^2$ (Provide 2H16, $A_s = 402\ mm^2$)

Tension steel, $A_s = \frac{0.129 \times 35 \times 300 \times 437^2}{0.87 \times 500 \times 379.8} + 233 \cdot \frac{392}{0.87 \times 500} = 1{,}776\ mm^2$ (Provide 3H32, $A_s = 2413\ mm^2$)

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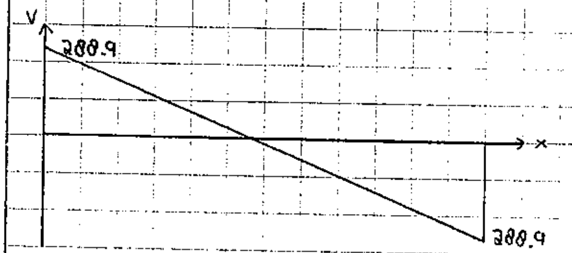
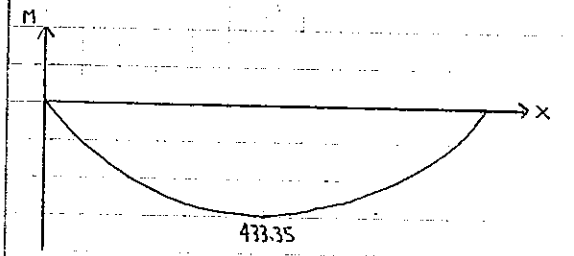
a Design load : $1.35(38) + 1.5(30) = 96.3$ kN/m



$V_{max} = \frac{96.3 \times 6}{2} = 288.9$ kN



$M_{max} = \frac{1}{8}(96.3)(6)^2 = 433.35$ kNm

a $b_f = 600$mm

Assume 32mm diameter bar, $d = 550 - 30 - 10 - \frac{32}{2} = 494$ mm

$K = \frac{433.35 \times 10^6}{600(494)^2(30)} = 0.099$, $f_a = 0.95$

$z = 0.95d = 469.3$ mm

$s = 2(d-z) = 2(494 - 469.3) = 49.4$ mm $< h_f$ (The stress block lies within the flange)

$A_s = \frac{433.35 \times 10^6}{0.87 \times 500 \times 469.3} = 2123$ mm² (Provide 3H32, $A_s = 2413$ mm²)

$\frac{100A_s}{bwd} = \frac{100(2413)}{250 \times 494} = 1.95\% > 0.13$ (OK!) (Serviceability check is on the next page)

b Shear stress at face of support, $V_s = 288.9 - 0.2 \times 96.3 = 269.64$ kN

$V_{Rd,max(22)} = 0.124(250)(494)(1 - 30/250)(30)$

$= 404.3$ kN > 269.64

$\therefore \theta = 22°$, $\cot\theta = 2.5$

At distance d from face support, $V_{Ed} = 269.64 - 0.494 \times 96.3 = 222.1$ kN

$\frac{A_{sw}}{s} = \frac{222.1 \times 10^3}{0.78(494)(500)(2.5)}$

$= 0.461$

Provide 10mm links at 300mm centres, $A_{sw}/s = 0.524$

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Minimum links, $\frac{A_{sw,min}}{s} = \frac{0.08 f_{ck}^{0.5} b_w}{f_{yk}}$

$= \frac{0.08 \times 30^{0.5} \times 250}{500}$

$= 0.219$

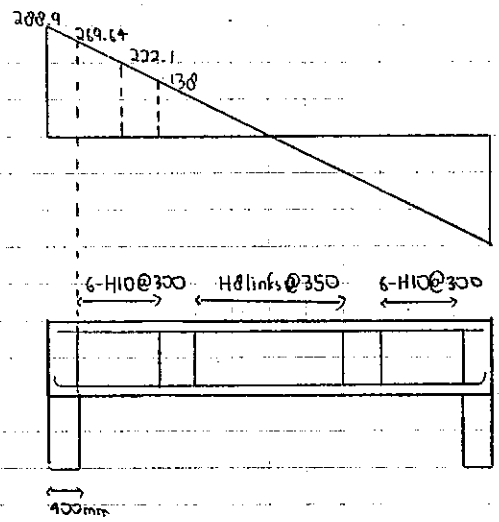
Provide 8mm links at 350mm centres, $A_{sw}/s = 0.287$

$V_{min} = 0.287 \times 0.78 \times 494 \times 500 \times 2.5 \times 10^{-3}$

$= 138\,kN$

$x = \frac{V_{Ed} - V_{min}}{w} = \frac{269.64 - 138}{96.3} = 1.37\,m$

Number of links required $= 1 + \left(\frac{1.37}{0.3}\right) = 6$ (Spaced over a distance of $(6-1)300 = 1500\,mm$)



Question 2a

$\rho = \frac{100 \times 2123}{250 \times 494} = 1.72\%$ For simply supported span, $K = 1.0$

Basic $l/d = 13$

Modified ratio for steel area provided $= \frac{2413}{2123} = 1.14$

Allowable $l/d = 13 \times 1 \times 1.14 = 14.82$

$L/d = 6000/494 = 12.1 < 14.82$ (OK!)

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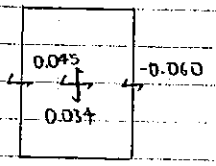
Design load : 1.35[(0.175×25) + 1] + 1.5×4.5 : 14 kN/m²

l_y / l_x : 7/5 : 1.4 (Two-way slabs)

For two short edges discontinuous , β_{sx} at continuous edge : 0.060

β_{sx} at mid-span : 0.045

β_{sy} at mid-span : 0.034



M_{sx} : 0.060 (14)(5)² : 21 kNm

M_{sx} : 0.045 (14)(5)² : 15.75 kNm

M_{sy} : 0.034 (14)(5)² : 11.9 kNm

d_x : 175 - 25 - 5 : 145 mm

d_y : 145 - 10 : 135 mm

Position	$K : \frac{M}{f_{ck} b d^2}$	Z (≤0.95d)	$A_{s,req}$ (mm²)	$A_{s,prov}$ (mm²)
Short edge mid-span	0.025	0.95×145 : 138	262	H10-200 (393 mm²)
Short edge at support	0.033	0.95×145 : 138	350	H10-200 (393 mm²)
Long edge mid-span	0.023	0.95×135 : 128	214	H10-300 (262 mm²)

$A_{s,min}$: $\max\left[0.26\left(\frac{f_{ctm}}{f_{yk}}\right) b d_y ;\ 0.0013\, b d_y\right]$

: $\max(0.0050\, b d_y ;\ 0.0013\, b d_y)$

: 203 mm²

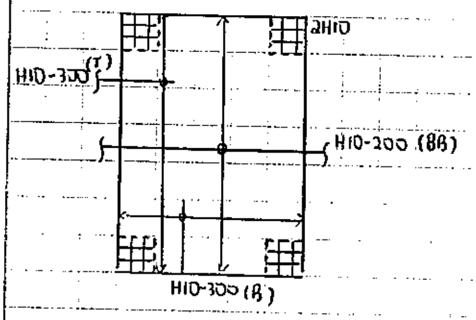
Top steel : 0.25 x A_{sx} mid-span : 0.25×393 : 98.25 mm² ≥ $A_{s,min}$

∴ Top steel reinforcement , A_s : 203 mm² , Provide H10-300

Torsion reinforcement , l : 5/5 : 1m

Corner A, B, C, D : 3/8 × A_{sx} : 3/8 × 262 : 98.25 mm²

Total area of torsion steel : 98.25×1 : 98.25 mm² ~ 2H10 (157 mm²)



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6 $l_y/l_x = 15/7 = 2.14 > 2$ (One-way slabs)

$d = 175 - 25 - 5 = 145\text{mm}$

Middle of end span, $M = 0.075FL$

$= 0.075\,w(5)(5)$

$= 1.875\,w$

Provide 10H-250, $A_s = 314\text{mm}^2$

$z = 0.95d = 137.75\text{mm}$

$M = 0.87 f_{yk} A_s z = 0.87 \times 500 \times 314 \times 137.75$

$= 18.81\text{ kNm}$

$M = 18.81 = 1.875w$

$18.81 = 1.875[1.35((0.175 \times 25) + 1) + 1.5 q_k]$

$q_k = 1.85\text{ kN/m}^2$

4 $A_{sc} = 0.03bh = 0.03(400)(500) = 6000\text{mm}^2$ $A_{col} = 400 \times 500 = 2 \times 10^5\text{ mm}^2$

$A_{sc1} = \frac{1}{3} \times 6000 = 2000\text{ mm}^2$

$A_{sc2} = \frac{2}{3} \times 6000 = 4000\text{ mm}^2$

0 Pure axial compression $(M = 0)$

$N = 0.567 f_{ck} \cdot A_{col} + 0.87 f_{yk} A_{sc}$

$= 0.567 \times 40 \times 2 \times 10^5 + 0.87 \times 500 \times 6000$

$= 7146\text{ kN}$ Point 1 (0, 7146)

6 Balance condition

$d/h = 0.9 \rightarrow d = 450\text{mm}$

$X_{bal} = 0.617d = 0.617 \times 450 = 277.65\text{ mm}$

$d'/x = 50/277.65 = 0.18 \leq 0.38$ (Compression steel has yielded)

$F_c = 0.567 \times 40 \times 400 \times 0.8(277.65) = 2015\text{ kN}$

$F_{s1} = 0.87 \times 500 \times 2000 = 870\text{ kN}$

$F_{s2} = 0.87 \times 500 \times 4000 = 1740\text{ kN}$

$N = F_c + F_{s1} + F_{s2}$

$= 4625\text{ kN}$

$M = F_c(\frac{h}{2} - 0.4x) + (F_{s1} + F_{s2})(d - \frac{h}{2})$

$= 2015(250 - 0.4 \times 277.65) + (870 + 1740)(450 - 250)$

$= 802\text{ kNm}$ Point 2 (802, 4625)

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Pure Bending Failure (N = 0)

Assume the compression steel has not yielded

$\varepsilon_{s1} = \dfrac{x-50}{x} \, 0.0035$

$f_{s1} = \varepsilon_{s1} \cdot E_s = \dfrac{x-50}{x} \times 700$

$$\Sigma F = 0$$

$$F_c + F_{s1} = F_{s2}$$

$$0.567 f_{ck} (400)(0.8x) + f_{s1} \times 2000 = 0.87 f_{yk} \times 4000$$

$$7257.6x + \frac{x-50}{x} 1.4\times10^6 = 1.74\times10^6$$

$$7257.6x^2 - 0.34\times10^6 x - 7\times10^7 = 0$$

$$x = 124.4 \text{ mm}$$

$f_{s1} = 418.6 \text{ N/mm}^2 < 0.87 f_{yk}$ (Assumption is correct)

Take moment about the tension steel

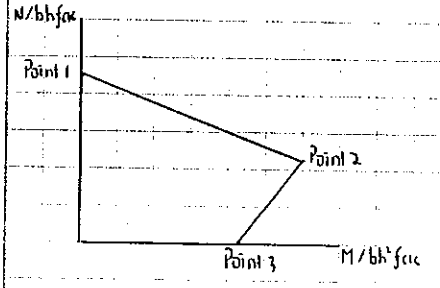
$M = F_c (d - 0.4x) + F_{s1}(d - 50)$

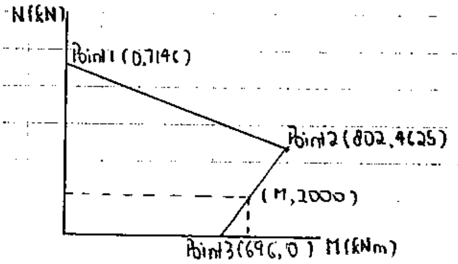
$= 0.567(40)(400)(0.8\times124.4)(450 - 0.4\times124.4) + 418.6\times2000(450-50)$

$= 696 \text{ kNm}$

Point 3 (696, 0)

Point	N (kN)	M (kNm)	N/bhf_{ck} (N/mm²)	M/bh^2f_{ck} (N/mm²)
1	7146	0	0.89	0
2	4625	802	0.58	0.2
3	0	696	0	0.17





$$\frac{M-696}{802-696} = \frac{2000-0}{4625-0}$$

$$M = 742 \text{ kNm}$$

$\therefore$ At N = 2000 kN, the maximum bending moment is, M = 742 kNm