



University of Technology
Building and Construction Engineering Department
Final Exam 2013-2014



Subject: Reinforced Concrete I
Division: Structural Engineering
Examiner:

Year: Third Year
Time: 3 Hours
Date: 8 / 6 / 2014

Answer Four Questions Only

Apply the ACI 318M-05 Specification, $f'_c = 23 \text{ N/mm}^2$, $f_y = 420 \text{ N/mm}^2$

- Q1) The continuous beam ABC shown in the figure (1) carries a uniformly distributed service dead load of (22.5 kN/m) (including beam self weight) and a uniformly distributed service live load of (25.5 kN/m). By using the Ultimate Strength Design Method, determine the longitudinal steel reinforcement required at section B and section E (draw sections with full details).
- Q2) The beam shown in the figure (2) is subjected to an ultimate torsional moment of ($T_U=13 \text{ kN.m}$). Design the necessary torsional reinforcement required for this beam. (use $\Phi 14\text{mm}$ closed stirrups and a clear cover of 50mm) (draw full section details).
- Q3) The simply supported beam shown in the figure (3) carries a uniformly distributed service dead load of magnitude ($2W \text{ kN/m}$) (without beam self weight). By using the Working Stress Design Method, find the maximum value of (W) that the beam can carry.
- Q4) The cantilever beam shown in the figure (4) carries a uniformly distributed service dead load of W_D (without beam self weight), and a concentrated service live load of (12 kN) at the free end, calculate:
- Maximum value of W_D that the beam can carry if the effective moment of inertia equals 1.14 of moment of inertia of the cracked section ($I_e=1.14 I_{cr}$), and the immediate deflection caused by dead and live loads is (6 mm).
 - Total deflection suppose that 30% of the live load is sustained.
- Q5) The reinforced concrete Two-Way slab shown in the figure (5) is supported by reinforced concrete beams of $600^{\text{mm}} \times 300^{\text{mm}}$. The slab supports a service distributed live load of (7 kN/m^2) and a service distributed dead load of (6 kN/m^2) (including slab self weight). Slab thickness is 140^{mm} . All columns are square of 300^{mm} . Design and detail the middle strip required bars A&B (using $\Phi 12^{\text{mm}}$ bars for the slab).

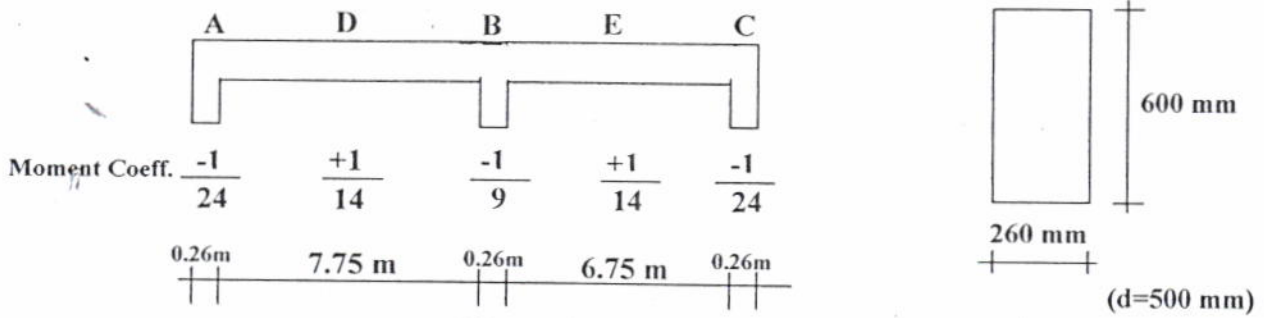


Figure (1)

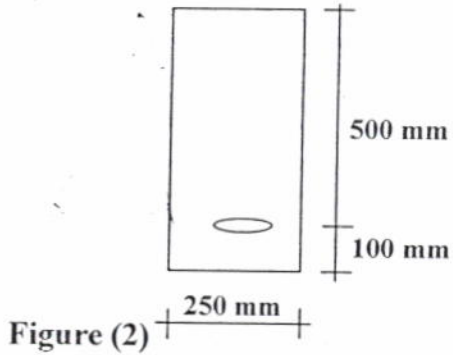


Figure (2)

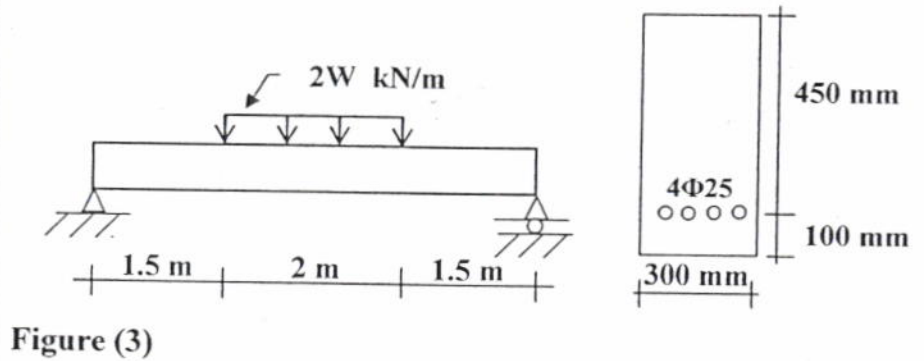


Figure (3)

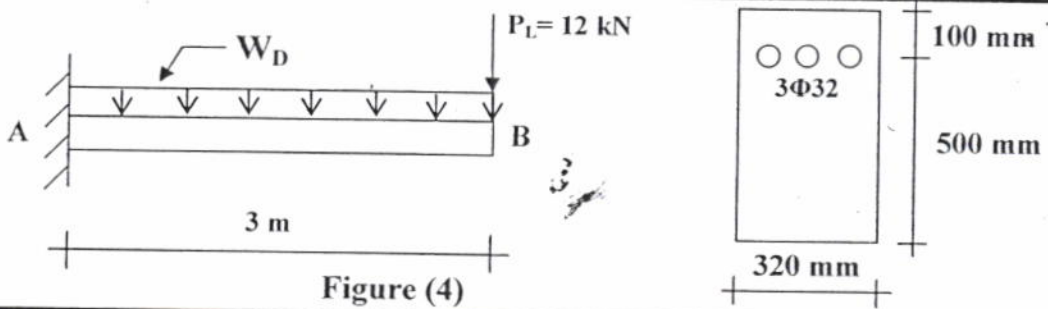


Figure (4)

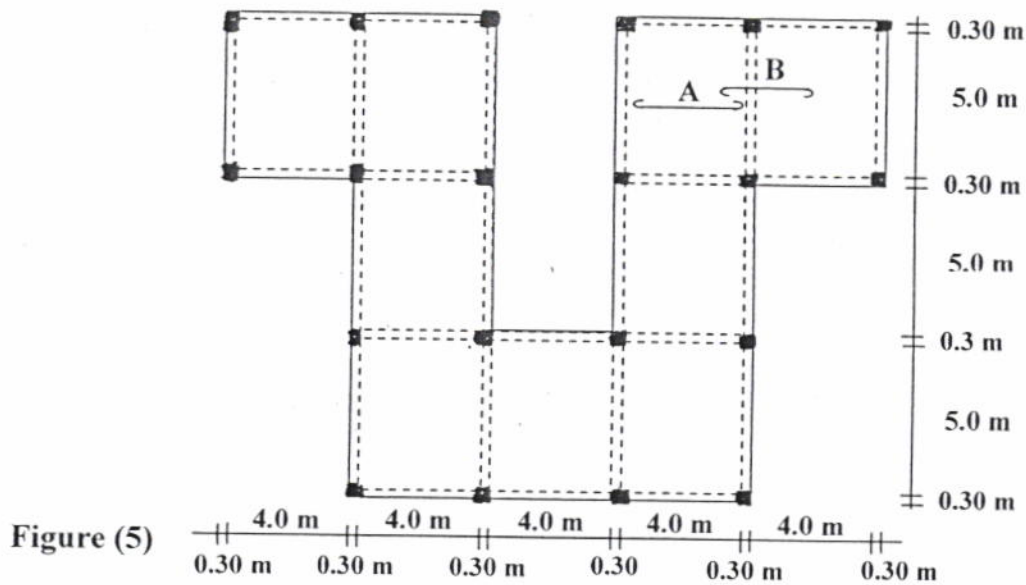


Figure (5)

Q1)

$$W_u = 1.2(22.5) + 1.6(25.5) = 67.8 \text{ KN/m}$$

$$M_{uB} = \frac{1}{9} \times 67.8 \times \left(\frac{7.75 + 6.75}{2} \right)^2 = 395.97 \text{ KN.m}$$

$$\rho_{max} = \frac{51 \times 0.85 \times 23}{140 \times 420} = 0.0169$$

$$A_{s1} = 0.0169 \times 260 \times 500 = 2197 \text{ mm}^2$$

$$d = \frac{2197 \times 420}{0.85 \times 23 \times 260} = 181.5 \text{ mm}$$

$$\text{max } M_u = 0.817 \times 2197 \times 420 \left(500 - \frac{181.5}{2} \right) \times 10^{-6}$$

$$\text{max } M_u = 308.51 \text{ KN.m} < M_{uB} = 395.97 \text{ KN.m}$$

∴ Doubly Reinf. conc. section

$$M_{u2} = 395.97 - 308.51 = 87.46 \text{ KN.m}$$

$$c = \frac{181.5}{0.85} = 213.5 \text{ mm}$$

$$\epsilon'_s = 0.003 \left(\frac{213.5 - 60}{213.5} \right) = 0.00215 > \epsilon_y = \frac{420}{200000} = 0.0021$$

$$\therefore f'_s = f_y ; A'_s = A_{s2}$$

$$A'_s = \frac{87.46 \times 10^6}{0.817 \times 420 \times (500 - 60)} = 580 \text{ mm}^2$$

use 3 ϕ 16

$$A_s = 2197 + 580 = 2777$$

6 ϕ 25

$$M_{u,E} = \frac{1}{14} * 67.8 * (6.75)^2 = 220.65 \text{ kN.m}$$

let $\phi = 0.9$; assume $a = 108 \text{ mm}$

$$A_s = \frac{220.65 * 10^6}{0.9 * 420 * (500 - \frac{108}{2})} = 1309 \text{ mm}^2$$

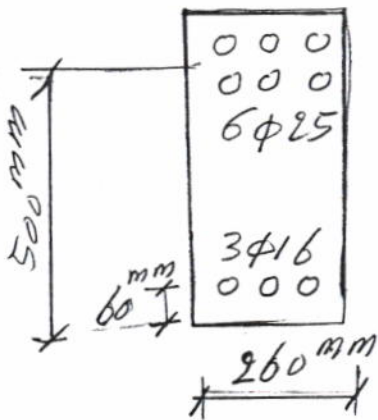
$$a = \frac{1312 * 420}{0.85 * 23 * 260} = 108.1 \text{ mm}$$

$$c = 127 \text{ mm}$$

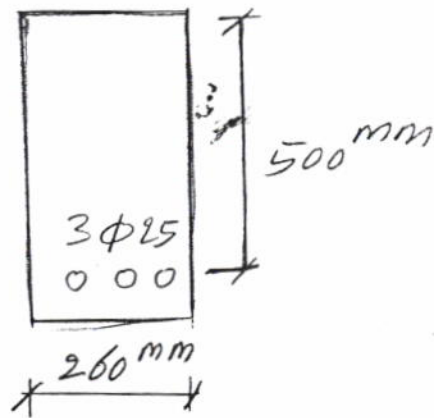
$$\phi = \left[0.65 + 0.25 \left(\frac{1}{127/500} - \frac{5}{3} \right) \right] \leq 0.9$$

$$\phi = 0.9 \quad \underline{0.1K}$$

use $3\phi 25$



sec. B



sec. E

Q2) $f'_c = 23 \text{ MPa}$, $f_y = 420 \text{ MPa}$.

Solution:

$$A_{cp} = 250 \times 600 = 150000 \text{ mm}^2, P_{cp} = (250 + 600) \times 2 = 1700 \text{ mm}$$

$$T_u = 13 \text{ kN}\cdot\text{m} > \phi 0.083 \sqrt{f'_c} \left(\frac{A_{cp}^2}{P_{cp}} \right) = 0.75 \times 0.083 \times \sqrt{23} \times \frac{(150000)^2}{1700 \times 10^6} = 3.95 \text{ kN}\cdot\text{m}$$

\therefore Torsional effect shall be consider.

$$y_1 = 600 - 2 \times 50 - 14 = 486 \text{ mm}, x_1 = 250 - 2 \times 50 - 14 = 136 \text{ mm}$$

$$A_{oh} = 136 \times 486 = 66096 \text{ mm}^2, P_h = (136 + 486) \times 2 = 1244 \text{ mm}$$

$$\frac{T_u \cdot P_h}{1.7 A_{oh}^2} \leq \phi 0.83 \sqrt{f'_c} \Rightarrow \frac{13 \times 10^6 \times 1244}{1.7 \times (66096)^2} = 2.18 < 0.75 \times 0.83 \times \sqrt{23} = 2.99 \text{ OK}$$

$$\frac{A_t}{s} = \frac{T_u}{1.7 A_{oh} f_{yv}} = \frac{(13/0.75) \times 10^6}{1.7 \times 66096 \times 420} = 0.367 \text{ mm}$$

$$\frac{A_t + 2A_t}{s} = 0 + 2 \times 0.367 = 0.734 \text{ mm}$$

$$\frac{A_t + 2A_t}{s} \geq 0.062 \sqrt{f'_c} \frac{b_w}{f_{yv}} \Rightarrow 0.734 > 0.062 \sqrt{23} \times \frac{250}{420} = 0.177 \text{ OK}$$

$$\frac{A_t + 2A_t}{s} \geq 0.35 \frac{b_w}{f_{yv}} \Rightarrow 0.734 > 0.35 \times \frac{250}{420} = 0.208 \text{ OK}$$

with $\phi 14 \text{ mm}$ closed stirrups $\Rightarrow A_t = 153.9 \text{ mm}^2$

$$\frac{A_t}{s} = 0.367 \text{ mm} \Rightarrow s = \frac{153.9}{0.367} = 419.3 \text{ mm}$$

$$s_{max} = \frac{P_h}{8} = \frac{1244}{8} = 155.5 \text{ mm or } 300 \text{ mm}$$

\therefore use $\phi 14 \text{ mm}$ closed stirrups @ 150 mm c/c.

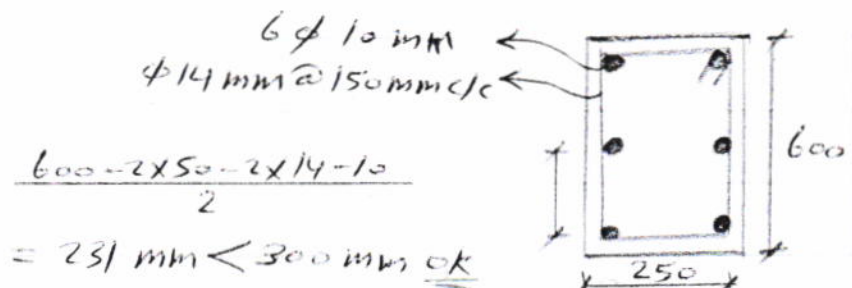
$$A_p = \frac{A_t}{s} \cdot P_h = 0.367 \times 1244 = 456.5 \text{ mm}^2$$

$$A_{p_{min}} = \frac{0.42 \sqrt{f'_c} \cdot A_{cp}}{f_y} - \frac{A_t}{s} P_h \frac{f_{yv}}{f_{yp}}, \text{ where } \frac{A_t}{s} = 0.367 > 0.175 \frac{b_w}{f_{yv}} = 0.175 \times \frac{250}{420} = 0.104 \text{ OK}$$

$$A_{p_{min}} = \frac{0.42 \sqrt{23} \times 150000}{420} - 456.5 = 719.4 - 456.5 = 262.9 \text{ mm}^2$$

bar dia. $\geq 0.042 S = 0.042 \times 150 = 6.3 \text{ mm or } 10 \text{ mm}$

\therefore use 6 $\phi 10 \text{ mm}$ bars ($A_p = 471 \text{ mm}^2 > 456.5 \text{ mm}^2$) OK



$$Q3) f_c = 23 \text{ MPa}, f_y = 420 \text{ MPa}.$$

Solution:

$$A_s = 1963 \text{ mm}^2.$$

$$E_c = 4700 \sqrt{f_c} = 4700 \sqrt{23} = 22540 \text{ MPa}.$$

$$n = E_s / E_c = 200000 / 22540 = 8.87 \approx 9.0$$

$$\frac{300 x^2}{2} = 9 \times 1963 \times (450 - x)$$

$$x^2 + 117.8 x - 53001 = 0$$

$$x = \frac{-117.8 \pm \sqrt{(117.8)^2 + 4 \times 53001}}{2} = 178.7 \text{ mm}.$$

$$I_{cr} = \frac{300(178.7)^3}{3} + 9 \times 1963 \times (450 - 178.7)^2 = 1.871 \times 10^9 \text{ mm}^4.$$

$$f_{c,all.} = 0.45 f_c = 0.45 \times 23 = 10.35 \text{ MPa}.$$

$$f_{s,all.} = 170 \text{ MPa}.$$

$$M_c = \frac{f_{c,all.} \times I_{cr}}{c} = \frac{10.35 \times 1.871 \times 10^9}{178.7 \times 10^6} = 108.365 \text{ kN}\cdot\text{m}.$$

$$M_s = \frac{f_{s,all.} \times I_{cr}}{n \times c} = \frac{170 \times 1.871 \times 10^9}{9 \times (450 - 178.7) \times 10^6} = 130.266 \text{ kN}\cdot\text{m}.$$

$$\therefore \text{use } M_{all.} = 108.365 \text{ kN}\cdot\text{m}.$$

$$W_D = 24 \times 0.3 \times 0.55 = 3.96 \text{ kN/m}$$

$$M_{all.} = \frac{3.96 \times (5)^2}{8} + 2W \times 2.5 - \frac{2W \times (1)^2}{2}$$

$$108.365 = 12.375 + 4W \Rightarrow W = 23.998 \text{ kN/m}.$$