University Of Technology
Building and Construction Eng. Dept.
Final Exam – First Attempt – 2010/2011

Subject : Reinforced Concrete I — Class: Third Year
Branch :Structural Engineering — Time : 3 Hours
Examiner : — Date :18 / 6 /2011

Note: Answer <u>Four</u> Questions Only.

Apply the ACI 318M-05 Specification, $f'_c = 27 \quad N/mm^2$, $f_y = 350 \quad N/mm^2$.

Q1) The beam shown in the figure (1) is subjected to an ultimate torsional moment (T_U=33 kN.m) and an ultimate shear force (V_U=300 kN). Design the necessary shear and torsional reinforcement required for this beam. (use Φ12mm stirrups and a clear cover of 50mm) (draw full section details).

Q2) Check the deflection of the cantilever beam shown in the figure (2) per ACI Code requirements. The beam carries a uniformly distributed service dead load of (18kN/m) (including beam self weight) and a uniformly distributed service live load of (12kN/m). Suppose that no part of the live load is sustained, and the construction is supporting to non structural elements not likely to be damaged by large deflections.

Q3) The continuous beam ABC shown in the figure (3) carries a uniformly distributed service dead load of (12 kN/m) (including beam self weight) and a uniformly distributed service live load of (17 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).

Q4) The cantilever beam shown in the figure (4) carries a uniformly distributed service dead load of (15kN/m) (including beam self weight) and a concentrated service live load (P_L) at the free end. By using the Working Stress Design Method find the maximum value of (P_L) that the beam can carry.

Q5) The reinforced concrete Two-Way slab shown in the figure (5) is supported by reinforced concrete beams of 650^{mm}x350^{mm}. The slab supports a service distributed live load of (6.5 kN/m^2) and a service distributed dead load of (6.0 kN/m^2). Slab thickness is 150^{mm}. All columns are square of 350^{mm}. Design and detail the middle strip required bars A&B (using Φ10^{mm} bars for the slab).

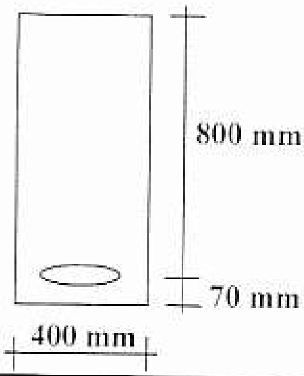

Figure (1)

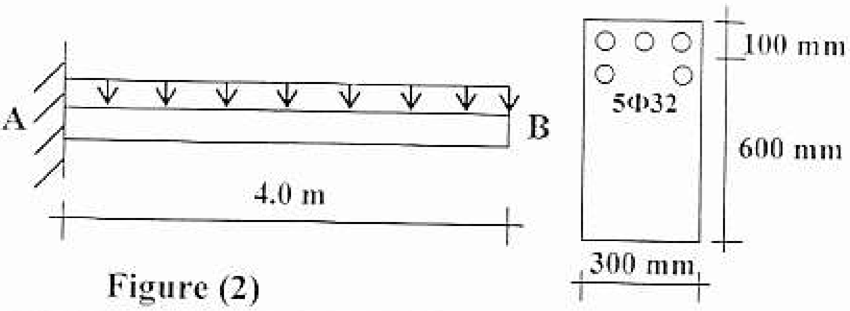

Figure (2)

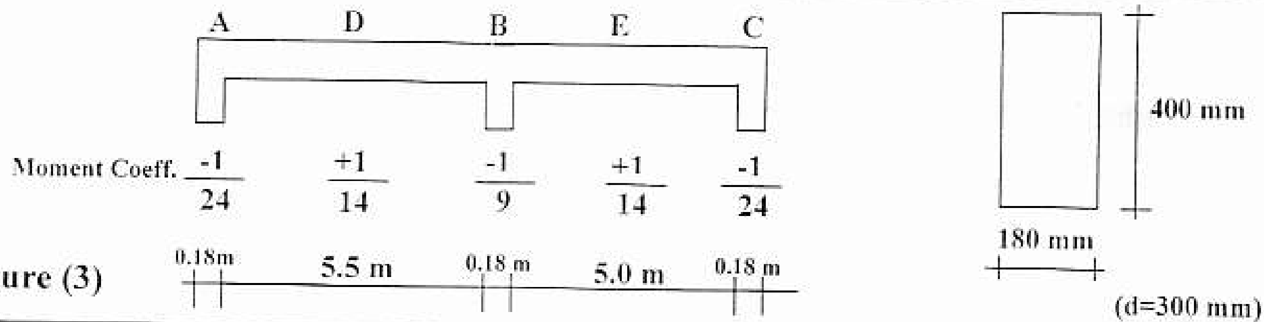

Figure (3)

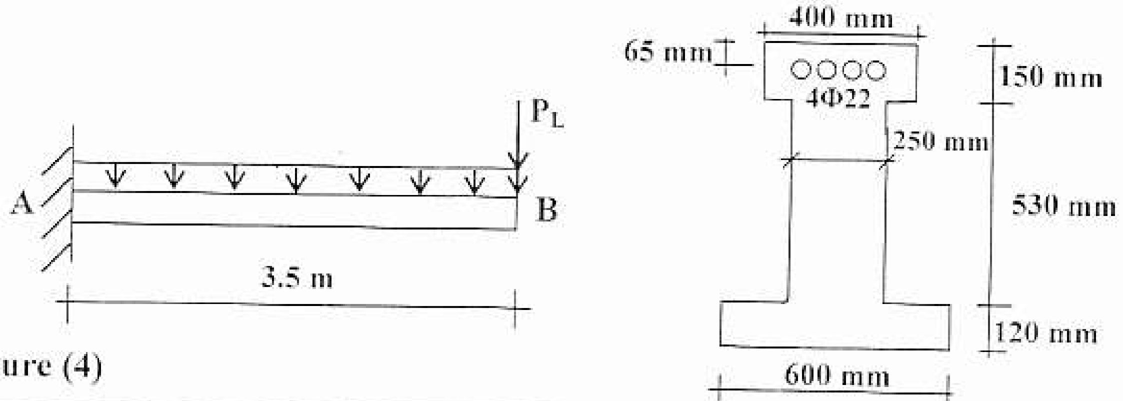

Figure (4)

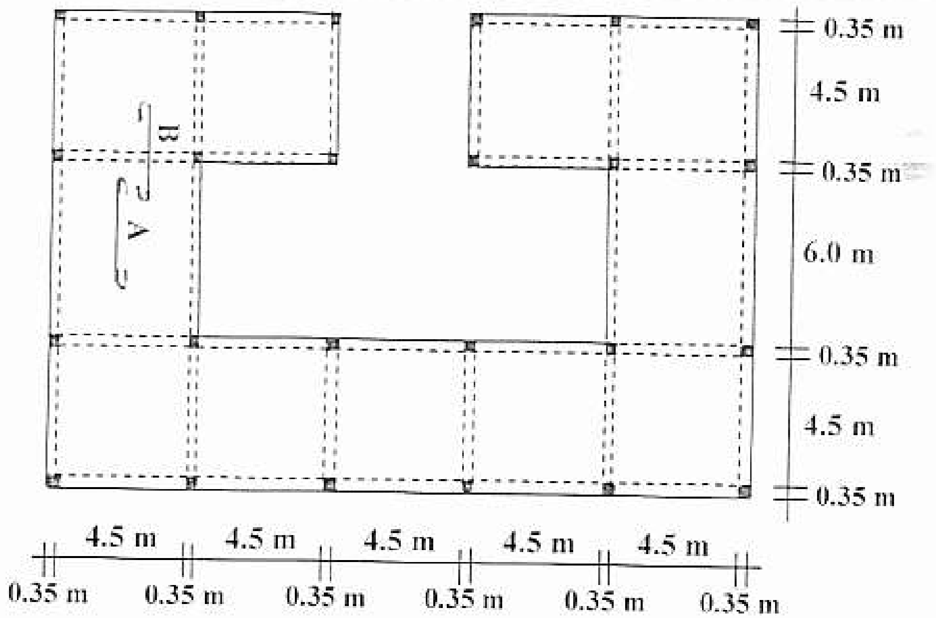

Figure (5)

$f_{c_{all}} = 0.45 f'_c$ $\quad f_{s_{all}} = 140 \ N/mm^2$ $\quad E_c = 4700\sqrt{f'_c}$ $\quad E_s = 200000 \ N/mm^2$

$$\phi = \left[\frac{7}{30} + \frac{0.2125\beta_1 f'_c}{\rho \ f_y}\right] \le 0.9 \qquad \rho_{min} = \frac{1.4}{f_y} \qquad \varepsilon'_s = 0.003\left(\frac{c-d'}{c}\right)$$

$$M_u = \phi \ \rho \ bd^2 f_y\left[1 - 0.59\rho\frac{f_y}{f'_c}\right] \qquad \bar{\rho}_{max} = \rho_{max} + \rho'\frac{f'_s}{f_y} \qquad \lambda = \frac{\xi}{1+50\rho'}$$

$$M_u = \phi\left[A_{s1} f_y\left(d - \frac{a}{2}\right) + A'_s f'_s(d-d')\right] \qquad M_{cr} = \frac{f_r I_g}{y_t} \qquad S = \frac{A_v f_y d}{V_s}$$

$$M_u = \phi \ A_s f_y (d - \frac{a}{2}) \qquad V_c = 0.17\sqrt{f'_c} b_w d \qquad A_{s,min} = 0.002 \ bh$$

$$I_{eff} = \left(\frac{M_{cr}}{M_a}\right)^3 I_g + \left[1 - \left(\frac{M_{cr}}{M_a}\right)^3\right] I_{cr} \le I_g \qquad f_r = 0.62\sqrt{f'_c} \qquad \rho_{max} = \frac{51\beta_1 f'_c}{140 \ f_y}$$

$$M_u = Coeff. \times W_u \times l_n^2 \qquad A_l = \frac{A_t}{S} P_h$$

S_{max} (two way slab) = 2h , 450 mm

$$\sqrt{\left(\frac{V_u}{b_w d}\right)^2 + \left(\frac{T_u P_h}{1.7 A_{oh}^2}\right)^2} \le \phi \ \left(\frac{V_c}{b_w d} + 0.66\sqrt{f'_c}\right) \qquad \frac{A_t}{S} = \frac{T_n}{1.7 A_{oh} f_{yt}}$$

$$\frac{A_v + 2A_t}{S} \ge 0.062\sqrt{f'_c}\frac{b_w}{f_{yt}} \qquad \frac{A_v + 2A_t}{S} \ge \frac{0.35 \ b_w}{f_{yt}} \qquad \Delta_B = \frac{wl^4}{8EI}$$

$$T_u \le \phi \ \ 0.083\sqrt{f'_c}\frac{A_{cp}^2}{p_{cp}} \qquad S_{max} = \frac{P_h}{8} \ \ or \ \ 300mm \qquad \gamma_{conc.} = 24 \ \ kN/m^3$$

$$A_{l,min} = \frac{0.42\sqrt{f'_c}A_{cp}}{f_{yl}} - \frac{A_t}{S}P_h\frac{f_{yt}}{f_{yl}} \quad where \frac{A_t}{S} \rangle \frac{0.175 b_w}{f_{yt}} \qquad bar \ \ dia. \ge \begin{matrix} 0.042 * S \\ 10 \ \ mm \end{matrix}$$

$$\max \ S \le \begin{matrix} d/2 \\ 600 \end{matrix} \ if \ V_s \le \frac{\sqrt{f'_c}}{3} b_w d \qquad \max \ S \le \begin{matrix} d/4 \\ 300 \end{matrix} \ if \ V_s > \frac{\sqrt{f'_c}}{3} b_w d$$

TABLE 9.5(b) — MAXIMUM PERMISSIBLE COMPUTED DEFLECTIONS

<table>
<tr><th>Type of Member</th><th>Deflection to be Considered</th><th>Deflection Limitation</th></tr>
<tr><td>Flat roofs not supporting or attached to nonstructural elements likely to be damaged by large deflections</td><td>Immediate deflection due to live load L</td><td>L /180</td></tr>
<tr><td>Roof or floor construction supporting or attached to nonstructural elements likely to be damaged by large deflections</td><td>Immediate deflection due to live load L</td><td>L /360</td></tr>
<tr><td>Roof or floor construction supporting or attached to nonstructural elements likely to be damaged by large deflections</td><td rowspan="2">That part of the total deflection occurring after attachment of nonstructural elements (sum of the long-term deflection due to all sustained loads and the immediate deflection due to any additional live load)</td><td>L /480</td></tr>
<tr><td>Roof or floor construction supporting or attached to nonstructural elements not likely to be damaged by large deflections</td><td>L /240</td></tr>
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Table 5.2 Coefficients for negative moments in slabs†

$M_{a,neg} = C_{a,neg} w l_a^2$
$M_{b,neg} = C_{b,neg} w l_b^2$ where w = total uniform dead plus live load

Ratio $m = \frac{l_a}{l_b}$		Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9
1.00	$C_{a,neg}$		0.045		0.050	0.075	0.071		0.033	0.061
	$C_{b,neg}$		0.045	0.076	0.050			0.071	0.061	0.033
0.95	$C_{a,neg}$		0.050		0.055	0.079	0.075		0.038	0.065
	$C_{b,neg}$		0.041	0.072	0.045			0.067	0.056	0.029
0.90	$C_{a,neg}$		0.055		0.060	0.080	0.079		0.043	0.068
	$C_{b,neg}$		0.037	0.070	0.040			0.062	0.052	0.025
0.85	$C_{a,neg}$		0.060		0.066	0.082	0.083		0.049	0.072
	$C_{b,neg}$		0.031	0.065	0.034			0.057	0.046	0.021
0.80	$C_{a,neg}$		0.065		0.071	0.083	0.086		0.055	0.075
	$C_{b,neg}$		0.027	0.061	0.029			0.051	0.041	0.017
0.75	$C_{a,neg}$		0.069		0.076	0.085	0.088		0.061	0.078
	$C_{b,neg}$		0.022	0.056	0.024			0.044	0.036	0.014
0.70	$C_{a,neg}$		0.074		0.081	0.086	0.091		0.068	0.081
	$C_{b,neg}$		0.017	0.050	0.019			0.038	0.029	0.011
0.65	$C_{a,neg}$		0.077		0.085	0.087	0.093		0.074	0.083
	$C_{b,neg}$		0.014	0.043	0.015			0.031	0.024	0.008
0.60	$C_{a,neg}$		0.081		0.089	0.088	0.095		0.080	0.085
	$C_{b,neg}$		0.010	0.035	0.011			0.024	0.018	0.006
0.55	$C_{a,neg}$		0.084		0.092	0.089	0.096		0.085	0.086
	$C_{b,neg}$		0.007	0.028	0.008			0.019	0.014	0.005
0.50	$C_{a,neg}$		0.086		0.094	0.090	0.097		0.089	0.088
	$C_{b,neg}$		0.006	0.022	0.006			0.014	0.010	0.003

Table 5.3 Coefficients for dead-load positive moments in slabs†

$M_{a,pos,dl} = C_{a,dl} w l_a^2$
$M_{b,pos,dl} = C_{b,dl} w l_b^2$ where w = total uniform dead load

Ratio $m = \frac{l_a}{l_b}$		Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9
1.00	$C_{a,dl}$	0.036	0.018	0.018	0.027	0.027	0.033	0.027	0.020	0.023
	$C_{b,dl}$	0.036	0.018	0.027	0.027	0.018	0.027	0.033	0.023	0.020
0.95	$C_{a,dl}$	0.040	0.020	0.021	0.030	0.028	0.036	0.031	0.022	0.024
	$C_{b,dl}$	0.033	0.016	0.025	0.024	0.015	0.024	0.031	0.021	0.017
0.90	$C_{a,dl}$	0.045	0.022	0.025	0.033	0.029	0.039	0.035	0.025	0.026
	$C_{b,dl}$	0.029	0.014	0.024	0.022	0.013	0.021	0.028	0.019	0.015
0.85	$C_{a,dl}$	0.050	0.024	0.029	0.036	0.031	0.042	0.040	0.029	0.028
	$C_{b,dl}$	0.026	0.012	0.022	0.019	0.011	0.017	0.025	0.017	0.013
0.80	$C_{a,dl}$	0.056	0.026	0.034	0.039	0.032	0.045	0.045	0.032	0.029
	$C_{b,dl}$	0.023	0.011	0.020	0.016	0.009	0.015	0.022	0.015	0.010
0.75	$C_{a,dl}$	0.061	0.028	0.040	0.043	0.033	0.048	0.051	0.036	0.031
	$C_{b,dl}$	0.019	0.009	0.018	0.013	0.007	0.012	0.020	0.013	0.007
0.70	$C_{a,dl}$	0.068	0.030	0.046	0.046	0.035	0.051	0.058	0.040	0.033
	$C_{b,dl}$	0.016	0.007	0.016	0.011	0.005	0.009	0.017	0.011	0.006
0.65	$C_{a,dl}$	0.074	0.032	0.054	0.050	0.036	0.054	0.065	0.044	0.034
	$C_{b,dl}$	0.013	0.006	0.014	0.009	0.004	0.007	0.014	0.009	0.005
0.60	$C_{a,dl}$	0.081	0.034	0.062	0.053	0.037	0.056	0.073	0.048	0.036
	$C_{b,dl}$	0.010	0.004	0.011	0.007	0.003	0.006	0.012	0.007	0.004
0.55	$C_{a,dl}$	0.088	0.035	0.071	0.056	0.038	0.058	0.081	0.052	0.037
	$C_{b,dl}$	0.008	0.003	0.009	0.005	0.002	0.004	0.009	0.005	0.003
0.50	$C_{a,dl}$	0.095	0.037	0.080	0.059	0.039	0.061	0.089	0.056	0.038
	$C_{b,dl}$	0.006	0.002	0.007	0.004	0.001	0.003	0.007	0.004	0.002

Table 5.4 Coefficients for live-load positive moments in slabs†

$M_{a,pos,ll} = C_{a,ll} w l_a^2$
$M_{b,pos,ll} = C_{b,ll} w l_b^2$ where w = total uniform live load

Ratio $m = \frac{l_a}{l_b}$		Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9
1.00	$C_{a,ll}$	0.036	0.027	0.027	0.032	0.032	0.035	0.032	0.028	0.030
	$C_{b,ll}$	0.036	0.027	0.032	0.032	0.027	0.032	0.035	0.030	0.028
0.95	$C_{a,ll}$	0.040	0.030	0.031	0.035	0.034	0.038	0.036	0.031	0.032
	$C_{b,ll}$	0.033	0.025	0.029	0.029	0.024	0.029	0.032	0.027	0.025
0.90	$C_{a,ll}$	0.045	0.034	0.035	0.039	0.037	0.042	0.040	0.035	0.036
	$C_{b,ll}$	0.029	0.022	0.027	0.026	0.021	0.025	0.029	0.024	0.022
0.85	$C_{a,ll}$	0.050	0.037	0.040	0.043	0.041	0.046	0.045	0.040	0.039
	$C_{b,ll}$	0.026	0.019	0.024	0.023	0.019	0.022	0.026	0.022	0.020
0.80	$C_{a,ll}$	0.056	0.041	0.045	0.048	0.044	0.051	0.051	0.044	0.042
	$C_{b,ll}$	0.023	0.017	0.022	0.020	0.016	0.019	0.023	0.019	0.017
0.75	$C_{a,ll}$	0.061	0.045	0.051	0.052	0.047	0.055	0.056	0.049	0.046
	$C_{b,ll}$	0.019	0.014	0.019	0.016	0.013	0.016	0.020	0.016	0.013
0.70	$C_{a,ll}$	0.068	0.049	0.057	0.057	0.051	0.060	0.063	0.054	0.050
	$C_{b,ll}$	0.016	0.012	0.016	0.014	0.011	0.013	0.017	0.014	0.011
0.65	$C_{a,ll}$	0.074	0.053	0.064	0.062	0.055	0.064	0.070	0.059	0.054
	$C_{b,ll}$	0.013	0.010	0.014	0.011	0.009	0.010	0.014	0.011	0.009
0.60	$C_{a,ll}$	0.081	0.058	0.071	0.067	0.059	0.068	0.077	0.065	0.059
	$C_{b,ll}$	0.010	0.007	0.011	0.009	0.007	0.008	0.011	0.009	0.007
0.55	$C_{a,ll}$	0.088	0.062	0.080	0.072	0.063	0.073	0.085	0.070	0.063
	$C_{b,ll}$	0.008	0.006	0.009	0.007	0.005	0.006	0.009	0.007	0.006
0.50	$C_{a,ll}$	0.095	0.066	0.088	0.077	0.067	0.078	0.092	0.076	0.067
	$C_{b,ll}$	0.006	0.004	0.007	0.005	0.004	0.005	0.007	0.005	0.004

Table 5.5 Ratio of load w in l_a and l_b directions for shear in slab and load on supports†

Ratio $m = \frac{l_a}{l_b}$		Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9
1.00	W_a	0.50	0.50	0.17	0.50	0.83	0.71	0.29	0.33	0.67
	W_b	0.50	0.50	0.83	0.50	0.17	0.29	0.71	0.67	0.33
0.95	W_a	0.55	0.55	0.20	0.55	0.86	0.75	0.33	0.38	0.71
	W_b	0.45	0.45	0.80	0.45	0.14	0.25	0.67	0.62	0.29
0.90	W_a	0.60	0.60	0.23	0.60	0.88	0.79	0.38	0.43	0.75
	W_b	0.40	0.40	0.77	0.40	0.12	0.21	0.62	0.57	0.25
0.85	W_a	0.66	0.66	0.28	0.66	0.90	0.83	0.43	0.49	0.79
	W_b	0.34	0.34	0.72	0.34	0.10	0.17	0.57	0.51	0.21
0.80	W_a	0.71	0.71	0.33	0.71	0.92	0.86	0.49	0.55	0.83
	W_b	0.29	0.29	0.67	0.29	0.08	0.14	0.51	0.45	0.17
0.75	W_a	0.76	0.76	0.39	0.76	0.94	0.88	0.56	0.61	0.86
	W_b	0.24	0.24	0.61	0.24	0.06	0.12	0.44	0.39	0.14
0.70	W_a	0.81	0.81	0.45	0.81	0.95	0.91	0.62	0.68	0.89
	W_b	0.19	0.19	0.55	0.19	0.05	0.09	0.38	0.32	0.11
0.65	W_a	0.85	0.85	0.53	0.85	0.96	0.93	0.69	0.74	0.92
	W_b	0.15	0.15	0.47	0.15	0.04	0.07	0.31	0.26	0.08
0.60	W_a	0.89	0.89	0.61	0.89	0.97	0.95	0.76	0.80	0.94
	W_b	0.11	0.11	0.39	0.11	0.03	0.05	0.24	0.20	0.06
0.55	W_a	0.92	0.92	0.69	0.92	0.98	0.96	0.81	0.85	0.95
	W_b	0.08	0.08	0.31	0.08	0.02	0.04	0.19	0.15	0.05
0.50	W_a	0.94	0.94	0.76	0.94	0.99	0.97	0.86	0.89	0.97
	W_b	0.06	0.06	0.24	0.06	0.01	0.03	0.14	0.11	0.03