Model Answer: Winter 2018

Subject: Design of R.C.C. Structure | **Sub. Code: 17604**

Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more importance. (Not applicable for subject English and Communication Skills.)
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by the candidate and those in the model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and the model answer.
6) In case of some questions credit may be given by judgment on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 1	(A)	**Attempt any THREE of the following :**		(12)
	(a)	**Define limit state and state types of various limit states.**		
	Ans.	**Limit State :** It may be defined as the acceptable limit for the safety and serviceability of the structure before failure occurs.	2	
		Types of various limit states :		
		(1) Limit state of collapse (a) Flexure (b) Shear (c) Torsion	1	
		(2) Limit state of serviceability (a) Deflection (b) Cracking	1	4
	(b)	**State the functions of reinforcement.**		
	Ans.	**Functions of reinforcement are as follows :** 1.In case of slab, beams and wall of water tanks, reinforcement is mainly provided to carry direct or bending tensile stresses. 2.In case of columns the steel is provided to resist the direct compressive stress as well as bending stresses if any. 3.In case of beams stirrups are provided to resist the diagonal tension due to shear and hold the main steel in position. 4.The box type mesh of reinforcement is provided to resist torsion. 5.The steel is provided in the form of rectangular, circular, lateral ties or spirals to prevent bucking of main bars in column. 6.The distribution steel is provided to distribute the concentrated loads and to reduce the effects of temperature and shrinkage and to hold main bars in position.	1 each (any four)	4

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 1	(c)	**State the reasons for providing shear reinforcement in the form of stirrups.**		
	Ans.	Reasons for providing shear reinforcement in the form of stirrups are as follows : 1. To prevent sudden failure. 2. To prevent premature failure if the bond between main steel and concrete is lost. 3. To act as tie for holding the beam reinforcement. 4. To confine the concrete.	1 each	4
	(d)	**Define magnitude of earthquake and intensity of earthquake.**		
	Ans.	**Magnitude of earthquake:** It is a measure of the amount of energy released. It is quantitative measure of the actual size or strength of the earthquake and it is much more precise measure than intensity.	2	
		Intensity of earthquake: It is an evaluation of the severity of the ground motion at a location and it is represented by a numerical value.	2	4
	(e)	**Explain the prestressed concrete. Also state the difference between externally and internally prestressed concrete members.**		
	Ans.	**Prestressed Concrete :** It is that concrete in which the compressive stresses are induced in the concrete section before the member is loaded by external loads.	2	
		Difference between externally and internally prestressed concrete members : (see table below)	1 each (any two)	4

Externally prestressed member	Internally prestressed member
1. Prestressing is achieved by elements located outside the concrete member.	1. Prestressing is achieved by elements located inside the concrete member.
2. This method is used for bridges and strengthening of building.	2. This method is used for small members.
3. This method requires greater degree of accuracy of planning and hence not commonly used.	3. In this method as greater degree of accuracy can be achieved, it is commonly used.

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 1	**(B)**	**Attempt any ONE :**		**(6)**
	(a)	**Find limiting moment of resistance and steel required for a beam 300 X 600 mm (effective), if concrete M25 and Fe 415 steel are used.**		
	Ans.	Given : b = 300 mm; d = 600 mm; f_{ck} = 25 N/mm^2; f_y = 415 N/mm^2. To find : M_u = ? A_{st} = ?		
		Solution : $Xu_{max} = 0.48 \times d = 0.48 \times 600 = 288\,mm$	1	
		$Mu_{lim} = (0.138) \times fck \times b \times d^2 = (0.138) \times 25 \times 300 \times 600^2$	1	
		$\boxed{Mu_{lim} = 372.6 \times 10^6\ Nmm}$ OR $\boxed{Mu_{lim} = 372.6\ kNm}$	1	
		$Xu_{max} = \dfrac{0.87 \times fy \times Ast}{0.36 \times fck \times b}$	1	
		$Ast = \dfrac{0.36 \times fck \times b \times Xu_{max}}{0.87 \times fy} = \dfrac{0.36 \times 25 \times 300 \times 288}{0.87 \times 415}$	1	
		$\boxed{Ast = 2153.718\,mm^2}$	1	6
		OR		
		For Fe 415, $\%pt = 0.048 \times fck = 0.048 \times 25 = 1.2\,\%$	1	
		$pt_{lim} = \dfrac{Ast}{b \times d} \times 100$		
		$Ast = \dfrac{pt_{lim} \times b \times d}{100} = \dfrac{1.2 \times 300 \times 600}{100}$	1	
		$\boxed{Ast = 2160\,mm^2}$		
	(b)	**Calculate A_{st} required for R.C.C. section 200 X 450 effective to resist an ultimate bending moment of 150 kNm. Assume M30 concrete and Fe 415 steel.**		

<table>
<tr><th>Que. No.</th><th>Sub. Que.</th><th>Model Answer</th><th>Marks</th><th>Total Marks</th></tr>
<tr><td>Q. 1</td><td>Ans.</td><td>Given :
b = 200 mm
d = 450 mm
Md = 150 kNm = 150 x 10^6 Nmm
f_{ck} = 30 N/mm^2
f_y = 415 N/mm^2
To find :
M_u = ?
A_{st} = ?</td><td></td><td></td></tr>
<tr><td></td><td></td><td>Solution :
$Mu_{lim} = (0.138) \times fck \times b \times d^2 = (0.138) \times 30 \times 200 \times 450^2$</td><td>1</td><td></td></tr>
<tr><td></td><td></td><td>$Mu_{lim} = 167.67 \times 10^6$ Nmm OR
$Mu_{lim} = 167.67$ kNm</td><td>1</td><td></td></tr>
<tr><td></td><td></td><td>Since, $Md = 150$ kNm < $Mu_{lim} = 167.67$ kNm,</td><td>1</td><td></td></tr>
<tr><td></td><td></td><td>Section is under - reinforced.</td><td>1</td><td></td></tr>
<tr><td></td><td></td><td>$$Ast = \frac{0.5 \times fck}{fy} \times \left[1 - \sqrt{1 - \frac{4.6 \times Md \times 10^6}{fck \times b \times d^2}}\right] \times b \times d$$</td><td>1</td><td></td></tr>
<tr><td></td><td></td><td>$$= \frac{0.5 \times 30}{415} \times \left[1 - \sqrt{1 - \frac{4.6 \times 150 \times 10^6}{30 \times 200 \times 450^2}}\right] \times 200 \times 450$$
$Ast = 1114.669$ mm^2</td><td>1</td><td>6</td></tr>
<tr><td>Q. 2</td><td></td><td>Attempt any TWO of the following :</td><td></td><td>(16)</td></tr>
<tr><td></td><td>(a)</td><td>Design a cantilever slab of 2 m span carrying super imposed load of 3 kN/m^2 including floor finish. Adopt M20 and Fe 415 steel. Sketch the c/s of slab showing all details. (No check required). Take end bearing as 230 mm.

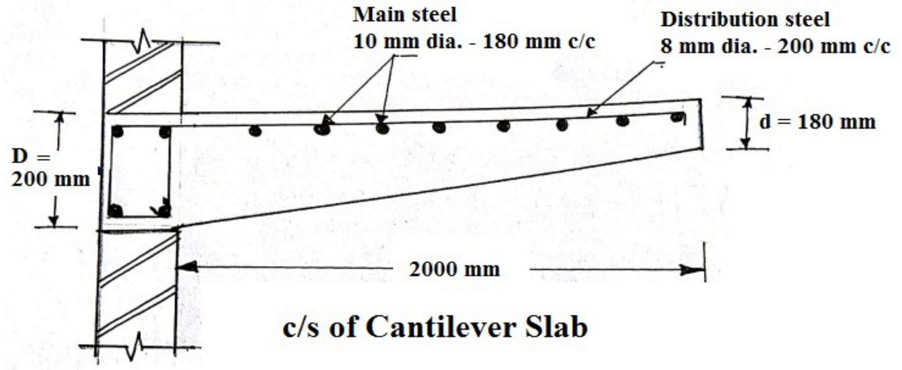
(NOTE : Answer may vary according to assumptions made by students)</td><td></td><td></td></tr>
<tr><td></td><td>Ans.</td><td>Given:
L = 2 m = 2000 mm
LL + FF = 3 kN/m^2
End bearing = 230 mm
f_{ck} = 20 N/mm^2
f_y = 415 N/mm^2
To find :
D = ?
Ast in both direction = ?

Assumptions :
C = 15 mm, ϕ_x = 10 mm, ϕ_y = 8mm</td><td></td><td></td></tr>
</table>

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 2	(a)	Step 1) Slab thickness $d=\frac{Span}{7\times M.F.}$ Assume, M. F. = 1.6, Cover =15 mm and $\phi_x = 10\,mm$ $d=\frac{2000}{7\times 1.6}= 178.571\,mm$ $D=d+c+\frac{\phi_x}{2}=178.571+15+\frac{10}{2}=198.571\,mm$ Provide, $D=200mm$, $d=200-15-\frac{10}{2}=180\,mm$ $\boxed{D=200\,mm,\ d=180\,mm}$	1	
		Step (2) Effective span $l_e=2000+\frac{180}{2}=2090\,mm=2.09\,m$	1	
		Step 3) Load cal. and BM i) D.L. of slab $=0.200\times1\times1\times25= 5.0$ kN/m ii) L.L.+ F.F. of slab $=3\times1\times1 = 3.0$ kN/m Total laod (w) = 8.0 kN/m Factored load $w_d=1.5\times8.0=12.0\,kN/m$	1	
		$BM=M_u=\frac{(wd)l_e^2}{2}=\frac{12\times2.09^2}{2}=26.209\,kN\text{-}m$	1	
		Step 4) Check for depth , $Mu_{max} = M_u$ $0.138\times f_{ck}\times b\times(d_{reqd})^2 = 26.209\times10^6$ $0.138\times20\times1000\times(d_{reqd})^2 = 26.209\times10^6$ $(d_{reqd})= 97.447\ mm < d=180\,mm$ ....Ok	1	

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 2	(a)	Step (5) Main steel and its spacing $A_{st}=\frac{0.5f_{ck}}{f_y}\left[1-\sqrt{1-\frac{4.6\times Mu\times 10^6}{f_{ck}bd^2}}\right]bd$ $A_{st}=\frac{0.5\times 20}{415}\left[1-\sqrt{1-\frac{4.6\times 26.209\times 10^6}{20\times 1000\times (180)^2}}\right]\times 1000\times 180$ $A_{st}=424.232\ mm^2$ $A_{st\,min}=\frac{0.12}{100}\times 1000\times 200=240\,mm^2$ $A_{st}=424.232\ mm^2 < A_{st\,min}=240\,mm^2$ Hence, $A_{st}=424.232\ mm^2$ Spacing of bar Min. of a) $S_x=\frac{1000\times A\phi_x}{A_{st}}=\frac{1000\times \frac{\pi}{4}(10)^2}{424.232}=185.134\,mm$ b) $S_x=3d=3\times 180=540\,mm$ c) $S_x=300\,mm$ $S_x=180$ mm c/c **[Provide 10 mm φ bars @ 180 mm c/c]**	1	
		Step 6) $Ast_y=Ast_{min}=\frac{0.12}{100}\times 1000\times 200=240\,mm^2$ Assuming, 8 mm ϕ bars. Spacing of bar = Min. of a) $S_y=\frac{1000\times A\phi_y}{A_{st\,y}}=\frac{1000\times \frac{\pi}{4}(8)^2}{240}=209.439\,mm$ b) $S_y=5d=5\times 180=900\,mm$ c) $S_y=450\,mm$ $S_y=200\,mm$ c/c **[Provide 8 mm φ bars @ 200 mm c/c]**	1	8

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 2	(a)	(figure below)	1	



c/s of Cantilever Slab

(b) **Design a roof slab for a room having inner dimensions as 3.0 X 4.5 m. The slab is simply supported on four sides of walls of 230 mm thick and corners are not held down. The live load is 2 kN/m². Use M20 concrete and Fe 415 steel. Take M.F. of 1.4. Sketch the cross section of slab along shorter span showing all details. (No check required).**

ly / lx = a	1.4	1.5
αx	0.099	0.104
αy	0.051	0.046

Ans. ***(NOTE : Answer may vary according to assumptions made by students)***

Given:
l_x = 3 m = 3000 mm
l_y = 4.5 m = 4500 mm
Wall thk. = 230 mm
LL = 2 kN/m^2
MF = 1.4
f_{ck} = 20 N/mm^2
f_y = 415 N/mm^2

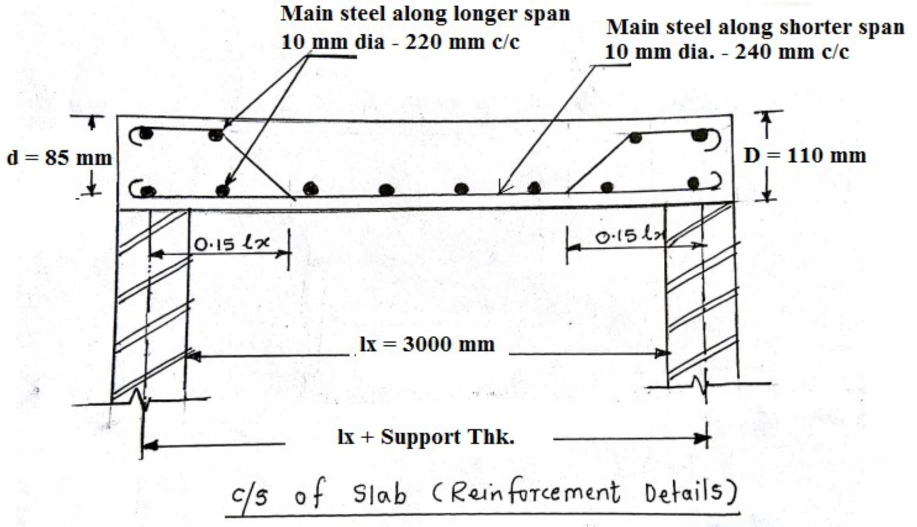
To find :
D = ?
Ast in both direction = ?

Assumptions :
FF = 1 kN/m^2
ϕ_x = 10 mm
C = 20 mm

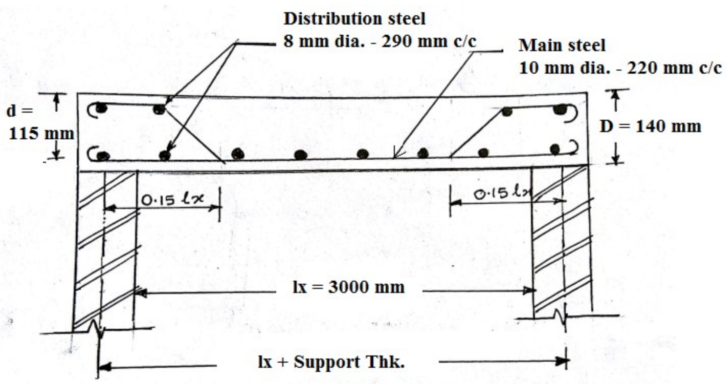
Solution:

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 2	(b)	Step (1) Slab thickness, as $l_x = 3\,m < 3.5\,m$ and $LL = 2\,kN/m^2 < 3\,kN/m^2$ and Fe 415 is used. $D = \frac{l_x \text{ in mm}}{28} = \frac{3000}{28} = 107.143$ mm Provide, $D = 110\,mm$ $d = D - c - \frac{\phi_x}{2} = 110 - 20 - \frac{10}{2} = 85$ mm	1	
		Step (2) Effective span $l_x = l_{xe} = l_x + d = 3000 + 85 = 3085$ mm $= 3.085\,m$ $l_y = l_{ye} = l_y + d = 4500 + 85 = 4585$ mm $= 4.585\,m$	1	
		Step (3) Load & B M calculation i) D.L. of slab = 0.11 × 1 × 1 × 25 = 2.75 kN/m ii) L.L. of slab = 2×1×1 = 2.50 kN/m iii) F.F. of slab = 1×1×1 = 1.00 kN/m Total load = 6.25 kN/m Factored load $(w_d) = 1.5 \times w$ $= 1.5 \times 6.25$ $= 9.375$ kN/m	1	
		BM calculations, $a = \frac{ly_e}{lx_e} = \frac{4.585}{3.085} = 1.486$ a — α_x — α_y 1.4 — 0.099 — 0.051 1.5 — 0.104 — 0.046 By interpolation, we get - $\alpha_x = 0.103$ and $\alpha_y = 0.047$ $Mu_x = \alpha_x . w_d . (l_{xe})^2 = (0.103 \times 9.375 \times (3.085)^2)$ $\boxed{Mu_x = 9.190\,kN\text{-}m}$ $Mu_y = \alpha_y . w_d . (l_{xe})^2 = (0.047 \times 9.375 \times (3.085)^2)$ $\boxed{Mu_y = 4.193\,kN\text{-}m}$	1	
		Step (4) Check for depth $Mu_{max} = M_{ux}$ $0.138 \times 20 \times 1000 \times (d_{reqd})^2 = 9.190 \times 10^6$ $(d_{reqd}) = 57.704\,mm < d = 85\,mm$ ....Ok	1	

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 2	(b)	Step (5) Main steel and its spacing In X direction $A_{stx}=\frac{0.5f_{ck}}{f_y}\left[1-\sqrt{1-\frac{4.6\times Mux\times 10^6}{f_{ck}bd^2}}\right]bd$ $A_{st}=\frac{0.5\times 20}{415}\left[1-\sqrt{1-\frac{4.6\times 9.190\times 10^6}{20\times 1000\times (85)^2}}\right]\times 1000\times 85$ $A_{st}=325.461\ mm^2$ Spacing of bar Min. of a) $S_x=\frac{1000\times A\phi_x}{A_{st}}=\frac{1000\times\frac{\pi}{4}(10)^2}{325.461}=241.318\,mm$ b) $S_x=3d=3\times 85=255\,mm$ c) $S_x=300\,mm$ $S_x=240\,mm$ c/c **Provide 10 mm ϕ bars @ 240 mm c/c** In Y direction $d'=d-\phi_x=85-10=75\,mm$ $A_{sty}=\frac{0.5f_{ck}}{f_y}\left[1-\sqrt{1-\frac{4.6\times Muy\times 10^6}{f_{ck}bd'^2}}\right]bd'$ $A_{sty}=\frac{0.5\times 20}{415}\left[1-\sqrt{1-\frac{4.6\times 4.193\times 10^6}{20\times 1000\times (75)^2}}\right]\times 1000\times 75$ $A_{sty}=162.200\,mm^2$ $A_{stmin}=\frac{0.12}{100}\times 1000\times 85=102\,mm^2$ $A_{sty}=162.200\,mm^2>A_{stmin}=102\,mm^2$ Using 10 mm dia. bar Spacing of bar Min. of a) $S_y=\frac{1000\times A\phi_y}{A_{sty}}=\frac{1000\times\frac{\pi}{4}(10)^2}{162.200}=484.215\,mm$ b) $S_y=3d'=3\times 75=225\,mm$ c) $S_y=300\,mm$ $S_y=220\,mm$ c/c **Provide 10 mm ϕ bars @ 220 mm c/c**	1 1	

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 2	(b)		1	8
	(c)	**The passage 3 m wide is supported on 230 mm thick side walls. It carries super imposed loads of 4 kN/sq. m including floor finish. Design a one way slab using M 20 concrete and Fe 415 steel. Take M.F. = 1.4. Sketch c/s of slab along shorter span showing reinforcement details. Check not required.**		
	Ans.	***(NOTE : Answer may vary according to assumptions made by students)*** Given: l = 3 m = 3000 mm t_s = 230 mm LL + FF = 4 kN/m^2 MF = 1.4 f_{ck} = 20 N/mm^2 f_y = 415 N/mm^2 To find : D = ? Ast in both direction = ? Assupmtion : ϕ_x = 10 mm ϕ_y = 8 mm C = 20 mm Step (1) $d=\frac{Span}{20\times MF}=\frac{3000}{20\times1.4}=107.143$ mm $D = d+c+\frac{\phi_x}{2}=107.143+20+\frac{10}{2}=132.143$ mm		

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 2	(c)	Provide, D =140 mm $d = 140 - 20 - \frac{10}{2} = 115$ mm	1	
		Step (2) Effective span Min. of (a) & (b) a) $l_e = l + d = 3000 + 115 = 3115$ mm = 3.115 m b) $l_e = l + t_s = 3000 + 230 = 3230$ mm = 3.230m $l_e = 3.115$ m	1	
		Step (3) Load & B M calculation i) D.L. of slab = $0.140 \times 1 \times 1 \times 25 = 3.5$ kN/m ii) L.L. + FF of slab = $4 \times 1 \times 1 = 4.0$ kN/m Total load = 7.5 kN/m Factored load $(w_d) = 1.5 \times w$ $= 1.5 \times 7.5$ $= 11.25$ kN/m	1	
		$BM = Mu = \frac{w_d (l_e)^2}{8} = \frac{11.25 \times (3.115)^2}{8}$ **BM = Mu=13.645 kN-m**	1	
		Step (4) Check for depth $Mu_{max} = M_u$ $0.138 f_{ck} b (d_{reqd})^2 = 13.645 \times 10^6$ $0.138 \times 20 \times 1000 \times (d_{reqd})^2 = 13.645 \times 10^6$ $(d_{reqd}) = 70.312$ mm $< d = 115$ mm ....Ok Step (5) Minimum area of reinforcement		
		$Ast_{min} = \frac{0.12}{100} bD = \frac{0.12}{100} \times 1000 \times 140 = 168\ mm^2$	1	

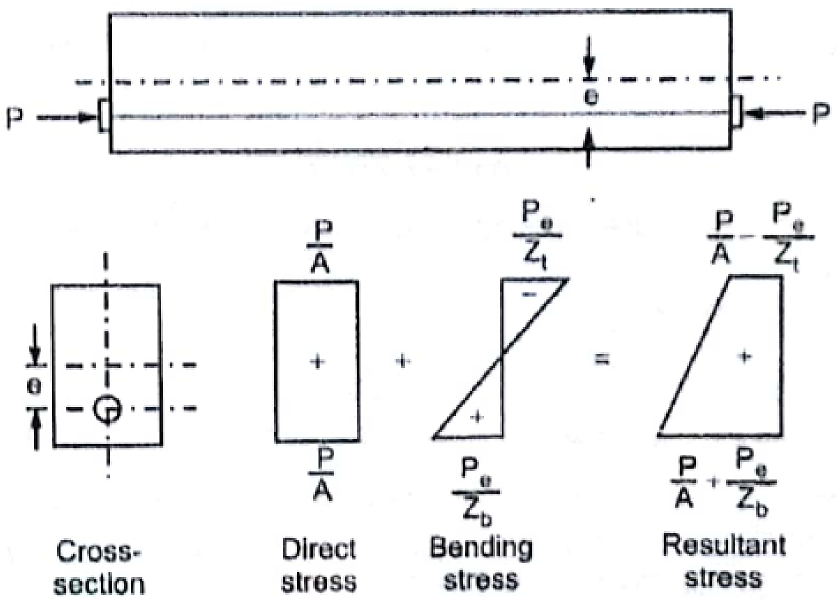
Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 2	(c)	Step (6) Main steel and its spacing $A_{st}=\frac{0.5f_{ck}}{f_y}\left[1-\sqrt{1-\frac{4.6\times Mu\times10^6}{f_{ck}bd^2}}\right]bd$ $A_{st}=\frac{0.5\times20}{415}\left[1-\sqrt{1-\frac{4.6\times13.645\times10^6}{20\times1000\times(115)^2}}\right]\times1000\times115$ $A_{st}=351.028\,mm^2$ Spacing of bar Min. of a) $S_x=\frac{1000\times A\phi_x}{A_{st}}=\frac{1000\times\frac{\pi}{4}(10)^2}{351.028}=223.742$ mm b) $S_x=3d=3\times115=345\,mm$ c) $S_x=300mm$ $S_x=220\,mm$ c/c Provide 10 mm ϕ bars @ 220 mm c/c along the shorter span	1	
		Step (7) Distribution steel and its spacing $Ast_{min}=\frac{0.12}{100}bD=\frac{0.12}{100}\times1000\times140=168\,mm^2$ Spacing of bars is equal to min. of a) $S_y=\frac{1000\times A\phi_y}{Ast_d}=\frac{1000\times\frac{\pi}{4}(8)^2}{168}=299.199\,mm$ b) $S_y=5d=5\times115=575\,mm$ c) $S_y=450mm$ $S_y=290\,mm$ c/c Provide 8 mm ϕ bars @ 290 mm c/c along the longer span	1	
		 c/s of Slab (Reinforcement Details)	1	8

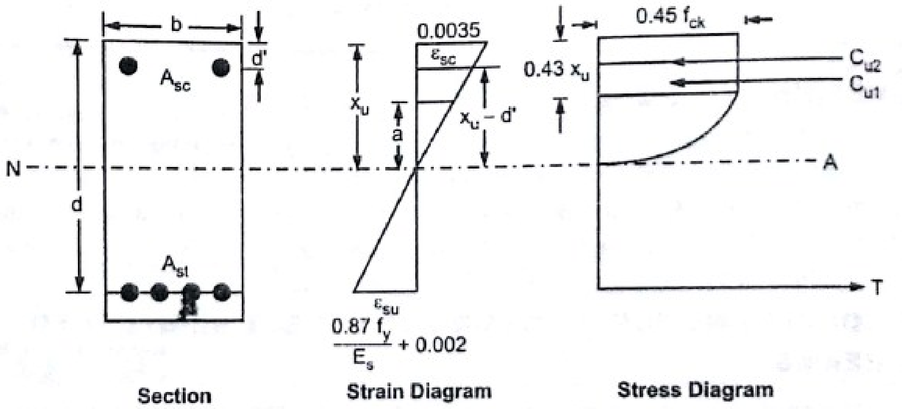
Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 3		**Attempt any FOUR of the following :**		**(16)**
	(a)	**Calculate safe load carrying capacity of short R.C.C. column 300 X 300 mm consisting of 4 bars of 16 mm ϕ and 2 bars of 12 mm ϕ. Use M 20 concrete and Fe 250 steel.**		
	Ans.	Step 1 Gross area, $A_g = 300 \times 300$ $= 90000\,mm^2$	1	
		Step 2 Area of steel $(A_{sc}) = \left[4 \times \left(\frac{\pi}{4}\right) \times (16)^2\right] + \left[2 \times \left(\frac{\pi}{4}\right) \times (12)^2\right]$ $= 1030.442\ mm^2$		
		Step 3 Area of concrete $(A_C) = Ag - A_{sc}$ $= 90000 - 1030.442$ $= 88969.557\ mm^2$	1	
		Step 4 Ultimate load carrying capacity (P_u) $P_u = (0.4 \times fck \times A_C) + (0.67 \times fy \times A_{sc})$ $= (0.4 \times 20 \times 88969.557) + (0.67 \times 250 \times 1030.442)$ $= 884.355 \times 10^3\ N$ $= 884.355\ kN$	1	
		Safe load carrying capacity (P) $P = \frac{Pu}{\gamma_f} = \frac{884.355}{1.5}$ $\boxed{P = 589.570\,kN}$	1	4
	(b)	**Write entire procedure step by step for providing shear reinforcement in an R.C.C. beam according to limit state method.**		
	Ans.	(1) Calculate factored shear force. (Vu) (2) Calculate nominal shear stress. $\varsigma_v = \frac{V_u\ in\ N}{b \times d} < \varsigma_{c\,max}$ (3) Find % pt of steel. $\%\,pt = \frac{Ast}{b \times d} \times 100$ (4) From % pt, calculate ζc. (5) If ζv > ζc, shear reinforcement is required. If ζv < ζc, shear reinforcement is not required. In such case, provide nominal shear reinforcement.		

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 3	(b)	6) Shear force for which shear reinforcement is required. $V_{us} = V_u - (\varsigma_c \times b \times d)$ (7) Assuming bent-up bars are not provided. Shear force to be resisted by stirrups. $V_{usv} = V_{us}$ (8) Spacing of stirrups = Min of following $(a)\, S_v = \frac{0.87 \times fy \times A_{sv}}{0.4 \times b}$ $(b) S_v = \frac{0.87 \times fy \times A_{sv} \times d}{V_{usv}}$ $(c) S_v = 0.75 \times d$ $(d) S_v = 300\,mm$	½ each step	4
	(c)	**Determine the development length of 16 mm diameter Fe 415 in compression, if design bond stress is 1.4 MPa for plain bar in tension.**		
	Ans.	Given data: φ = 16 mm, fy = 415 N/mm², $\tau_{bd} = 1.4\,N/mm^2$, bar is in compression $L_d = \frac{0.87 \times fy \times \phi}{4 \times \tau_{bd}'}$	1	
		$= \frac{0.87 \times 415 \times 16}{4 \times 1.6 \times 1.25 \times 1.4}$ ($\tau_{bd}' = 1.6 \times 1.25 \times \tau_{bd}$ ---- for deformed bar the value of τ_{bd} increased by 60% and for bar in compression τ_{bd} shall be increased by 25 %.)	2	
		$\boxed{L_d = 515.785\,mm}$	1	4
	(d)	**Write provision of flange width of T beam as per I. S., state meaning of each term.**		
	Ans.	Provision of flange width of T beam as per I. S.:- $b_f = \frac{l_0}{6} + b_w + 6D_f$	2	
		where, b_f = Effective width of flange l_o = Distance between points of zero moment in the beam b_w = Breath of web D_f = Thickness of flange b = Actual width of flange.	2	4

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 3	(e)	**Find moment of resistance (Mu) of a T beam with following data – b_f = 1500 mm, b_w = 300 mm, d = 700 mm, D_f = 100 mm, A_{st} = 2500 mm^2. Concrete M20 and Fe 415 steel.**		
	Ans.	**Given :** bf = 1500mm Df = 100mm bw = 300mm d =700mm Ast = 2500 mm^2 **To find M_u** **Step 1)** To find Xu=? (Assume Xu<Df) $X_u = \frac{0.87 \times fy \times Ast}{036 \times fck \times bf}$ $= \frac{0.87 \times 415 \times 2500}{0.36 \times 20 \times 1500}$	1	
		$X_u = 83.576\,mm < D_f = 100\,mm$ -----OK **Step 2)** To find X_{umax} X_{umax} = 0.48 X d = 0.48 X 700 X_{umax}=336 mm	1	
		As, X_u<X_{umax}, So, beam is under reinforced.	1	
		Step 3) **To find Mu=?** Mu = Tu x Zu = 0.87 x fy x Ast (d -0.42 Xu) = 0.87 x 415 x 2500 (700 - 0.42 x 83.576) = 600.153 x 10^6 N-mm **Mu = 600.153 KN-m**	1	4

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 4	**(A)**	**Attempt any THREE of the following :**		**(12)**
	(a)	**Describe process of prestressing and draw stress distribution diagram for it across a section.**		
	Ans.	***(NOTE : Procedure of prestressing for any one method should be considered)***		
		There are two methods of prestressing – (1) Pre-tensioning Method (2) Post-tensioning method		
		Process in Pre-tensioning method : • For prestressing by this method, the reinforcements or tendons are placed on the casting bed in the design position. • The required tension is applied in them and are anchored with the anchor posts provided at each end of the casting bed. • The formwork is re-erected around the tensioned tendons. Concrete is then poured in the prepared formwork and is compacted and cured. As soon as the concrete has fully hardened and developed the desired strength, the connections between the tendons and the anchor posts are cut-off • Due to bond between steel and concrete, the tensioned tendons, as they try to shorten, transfer the induced forces to the concrete. • This compresses the hardened concrete member and it is prestressed. Sometimes special anchorage is provided at the end of the member, when bond between concrete and tendon is not sufficient to retain the applied tension.	**2**	
		<u>OR</u>		
		Process in Pre-tensioning method : • For prestressing by this method, the prestressing force is applied to the tendons after the concrete has completely set and has attained the desired strength. The tendons are not bonded to concrete before tensioning. • The tendons are stretched through ducts left for them in the precast concrete member. The stretching of the cables is done with the help of jacks acting against the end of the precast member. • The tendons is placed in a flexible metal tube and anchor fitting are attached to the end of the cable. • The complete assembly is placed in already prepared formwork of the member to be concreted and kept in position by means of special spacers. • Concrete is poured and allowed to harden till it attains the required strength.	**2**	

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 4	(a)	• The tendon can freely move inside the hardened concrete as it is not in contact with concrete. • The prestressing force is created by tensioning the cable using hydraulic jack. • The anchorage at the ends of the tendons are adjusted to keep the stretched tendons firmly in position • Now, cement grout is forced under pressure to fill the space around the tendons completely. • Finally the anchorages are covered with a protective coat of grout. **Stress distribution diagram for prestressing**  Stress distribution diagram for prestressing	2	4
	(b) Ans.	**Justify over reinforced sections are disallowed in L.S.M.** 1) In over-reinforced section, percentage of steel is more than critical percentage. 2) Due to this, the concrete crushes reaching its ultimate strain before steel reaching its yield point. 3) In this case, the beam will fail initially due to overstress in the concrete, suddenly without giving any warning. 4) Therefore, design codes restrict the percentage of steel in RC sections to that of balanced section thus disallowing over- reinforced section.	4	4

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 4	**(c)**	**Draw stress and strain diagram for doubly reinforced section in L.S.M. State meaning of each term.**		
	Ans.	 **Stress-Strain in a Doubly Reinforced Section**	3	
		Where, b = Width of beam d = Effective depth d' = cover to compression reinforcement A_{st} = Area of steel in tension A_{sc} = Area of steel in compression X_u = Depth of neutral axis.	1	4
	(d)	**Design a circular column to carry an axial load of 1500 kN. Using MS lateral ties. Use M25 concrete and Fe 415 steel. The unsupported length of column is 3.75 m.**		
	Ans.	***(NOTE : According to assumption of % steel, answer may vary)*** $\text{Factored load } (P_u) = 1.5\times1500 = 2250\,\text{kN}$	1	
		$\text{Assume } 0.8\% \text{ of } A_g \text{ for compression steel}$ $A_{sc} = 0.008\times A_g$ $P_u = (0.4\times fck\times A_c)+(0.67\times fy\times A_{sc})$ $2250\times10^3 = (0.4\times25\times(A_g - A_{sc}))+(0.67\times415\times(0.008\times A_g))$ $2250\times10^3 = (0.4\times25\times(A_g - 0.008\times A_g))+(0.67\times415\times(0.008\times A_g))$ $A_g = 185270\,\text{mm}^2$		
		Dia. of circular column $D=\sqrt{\frac{4\times A_g}{\pi}}=\sqrt{\frac{4\times185270}{\pi}}=485.7\,\text{mm}$ say, D = 500 mm	1	

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 4		Slenderness Ratio $= \frac{L}{D} = \frac{3750}{500} = 7.5 < 12$ Hence, column is short. $A_{sc} = 0.008 \times A_g = A_{sc} = 0.008 \times \frac{\pi}{4} \times 500^2 = 1571\,mm^2$ Provide, 8-16 mm ϕ bars. A_{sc} provided $= 8 \times \frac{\pi}{4} \times 16^2 = 1608\,mm^2$	1	
		Diameter of links $= \frac{1}{4} \times \phi_L$ or 6 mm whichever is greater $= \frac{1}{4} \times 16$ or 6 mm whichever is greater $= 6\,mm$ Spacing of links = Min. of following (a) S = D = 500 mm (b) $S = 16 \times \phi_L = 16 \times 16 = 256\,mm$ (c) S = 300 mm Hence, provide 6 mm ϕ links at 250 mm c/c	1	4
	(B)	**Attempt any ONE of the following :**		(6)
	(a)	**Find the moment of resistance of the beam 250 X 500 mm deep if it is reinforced with 4 – 20 mm diameter bars in tension zone and 2 – 12 mm diameter bars in compression zone, each at an effective cover of 40 mm. Assume M15 concrete and Fe 415 steel.**		
	Ans.	***(NOTE : Answer may vary according to assumption made by students)*** Given: b = 250 mm D = 500 mm C = 40 mm d = D – C = 460 mm To find : M_u = ? $Ast = 4 \times \frac{\pi}{4} \times 20^2 = 1256.64\,mm^2$ $Asc = 2 \times \frac{\pi}{4} \times 12^2 = 226.19\,mm^2$ f_{ck} = 15 N/mm^2 f_y = 415 N/mm^2 Assuming: f_{sc} = 353 N/mm^2		

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 4	**(a)**	Step 1 :Find $X_{umax} = 0.48d$ ------ for Fe415 $= 0.48 \times 460$ $X_{umax} = 220.8$ mm	**1**	
		Step 2 : Find Ast_2 $f_{cc} = 0.45 \times f_{ck} = 0.45 \times 15 = 6.75$ N/mm^2 $Ast_2 = \frac{(f_{sc} - f_{cc}) \times A_{sc}}{0.87 \times f_y} = \frac{(353-6.75) \times 226.19}{0.87 \times 415}$	**1**	
		$Ast_2 = 226.918$ mm^2 $Ast_1 = Ast - Ast_2 = 1256.64 - 226.918 = 1029.722$ mm^2	**1**	
		Step 3 : Find Xu_1 $Xu_1 = \frac{0.87 \times f_y \times Ast_1}{0.36 \times f_{ck} \times b} = \frac{0.87 \times 415 \times 1029.722}{0.36 \times 15 \times 250} = 275.393$ mm	**1**	
		Step 4 : Find type of section As $Xu_1 = 275.393$ mm $> X_{umax} = 220.8$ mm Section is over-reinforced.	**1**	
		Step 5 : Find Moment of Resistance M_u $M_u = (0.138 \times fck \times b \times d^2) + \left[(f_{sc} - f_{cc}) \times A_{sc} (d - d')\right]$ $M_u = (0.138 \times 15 \times 250 \times 500^2) + \left[(353-6.75) \times 226.19 \times (460-40)\right]$ $M_u = 162.268 \times 10^6$ N-mm $\boxed{M_u = 162.268 \text{ kN-m}}$	**1**	**6**
	(b)	**A beam is required to resist a total B.M. of 120 kNm. The size of beam is limited to 300 mm X 610 mm overall. Clear cover on both sides is 30 mm. Calculate reinforcement in form of 20 mm diameter on both sides. Use (M15 and Fe 415).**		
	Ans.	Given: b = 300 mm D = 610 mm C = d' = 30 mm d = D – C = 580 mm M = 120 kNm f_{ck} = 15 N/mm^2 f_y = 415 N/mm^2 To find : Ast = ? Asc = ? Assumtion : f_{sc} = 353 N/mm^2		

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 4	(b)	Step 1)		
		$M_d = M_u = 1.5 \times M = 1.5 \times 120 = 180\,kNm$	1	
		Step 2) To find M_{u_1}		
		$M_{u_1} = M_{ulim} = 0.138 f_{ck} bd^2$	1	
		$= 0.138 \times 15 \times 300 \times 580^2$		
		$= 208.904 \times 10^6 N\text{-}mm > M_u = 180\,kNm$	1	
		Hence, beam is singly reinforced beam.		
		Step 3) To find A_{st_1}		
		$Pt_{lim} = 0.048fck = 0.048 \times 15 = 0.72\%$ ---- for M20 Concrete	1	
		$A_{st_1} = \frac{Pt_{lim} \times bd}{100} = \frac{0.72 \times 300 \times 580}{100}$	1	
		$\boxed{A_{st_1} = 1252.8\,mm^2}$		
		Using, 20 mm dia. bar.		
		No. of bar = $\frac{A_{st_1}}{\left(\frac{\pi}{4}\right) \times d^2} = \frac{1252.8}{\left(\frac{\pi}{4}\right) \times 20^2} = 3.98 = 4$	1	6
		Provide 4-20 mm dia. bar on tension side only.		
Q. 5		**Attempt any TWO :**		**(16)**
	(a)	**Design a rectangular beam for an effective span of 5.85 m. The super imposed load is 70 kN/m and size of beam is limited to 300 X 700 mm overall. Use M20 and Fe415. Assume a cover of 40 mm**		
	Ans.	***(NOTE : Answer may vary according to assumption made by student)***		
		Given: b = 300 mm; D = 700 mm; C = 40 mm; d = D – C = 660 mm; w = 70 kN/m; l = 5.85 m = 5850 mm; f_{ck} = 20 N/mm^2; f_y = 415 N/mm^2		
		To find : Ast = ? Asc = ?		
		Assumption : f_{sc} = 353 N/mm^2		

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 5	(a)	Solution: $w_d = w \times \gamma_f = 70 \times 1.5 = 105\,kN/m$ $M_d = \frac{w_d \times l^2}{8} = \frac{105 \times 5.85^2}{8} = 449.170\,kNm$	1	
		$M_{d_1} = 0.138 \times fck \times b \times d^2 = 0.138 \times 20 \times 300 \times 660^2$ $= 360.676 \times 10^6$ Nmm $= 360.676\,kNm$	1	
		As $M_d = 449.170\,kNm > M_{d_1} = 360.676\,kNm$, Section is doubly reinforced.	1	
		$\%pt_{lim} = 0.048 \times fck = 0.048 \times 20 = 0.96\%$ $A_{st1} = \frac{pt_{lim} \times b \times d}{100} = \frac{0.96 \times 300 \times 660}{100} = 1900.8\,mm^2$	1	
		$M_{d_2} = M_d - M_{d_1} = 449.170 - 360.676 = 88.494\,kNm$ $f_{cc} = 0.45 \times fck = 0.45 \times 20 = 9\,N/mm^2$ $f_{sc} = 353\,N/mm^2$ ----Assumed	1	
		$A_{sc} = \frac{M_{d_2}\text{ in Nmm}}{(f_{sc} - f_{cc}) \times (d - d')} = \frac{88.494 \times 10^6}{(353-9) \times (660-40)}$ $= 414.919\,mm^2$	1	
		Equating, $Cu_2 = Tu_2$ $(f_{sc} - f_{cc}) \times A_{sc} = A_{st2} \times 0.87 \times fy$ $A_{st2} = \frac{(f_{sc} - f_{cc}) \times A_{sc}}{0.87 \times fy} = \frac{(353-9) \times 414.919}{0.87 \times 415} = 395.325\,mm^2$	1	
		$A_{st} = A_{st1} + A_{st2} = 1900.8 + 395.325$ $= 2296.125\,mm^2$	1	8
	(b)	**Design a shear reinforcement for a beam of 6 m span having 25 kN/m udl . Beam size 300 mm X 600 mm overall, 30 mm cover. The reinforcement consist of 6 bars of 25 mm diameter. Concrete is M20 grade and steel of 415 grade.**		

Pt (%)	1.0	1.25	1.5	1.75	2.0
ζc	0.6	0.64	0.68	0.71	0.71

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks

Q. 5 (b) Ans.

Given:

b = 300 mm

D = 600 mm

C = 30 mm

d = D – C = 570 mm

l = 6 m = 6000 mm

w = 25 kN/m

$$Ast = 6\times\frac{\pi}{4}\times(25)^2 = 2945.243\, mm^2$$

f_{ck} = 20 N/mm^2

f_y = 415 N/mm^2

To find :

Spacing of stirrups = ?

Step 1) Factored Shear Force

$$w_d = 1.5\times w = 1.5\times 25 = 37.5\, kN/m$$

1

$$V_u = \frac{w_d\times l}{2} = \frac{37.5\times 6}{2} = 112.5\, kN$$

Step 2) Nominal shear stress

1

$$\varsigma_v = \frac{V_u}{b\times d} = \frac{112.5\times 10^3}{300\times 570} = 0.658\, N/mm^2 < \varsigma_{c\,max} = 2.8\, N/mm^2$$

Step 3) Shear strength of concrete (ς_c)

1

$$\% pt = \frac{A_{st}}{b\times d}\times 100 = \frac{2945.243}{300\times 570}\times 100 = 1.72\,\%$$

Pt (%)	1.5	1.75
ς_c	0.68	0.71

By interpolation

1

$$\varsigma_c = 0.7064\, N/mm^2$$

As $\varsigma_v = 0.658\, N/mm^2 < \varsigma_c = 0.7064\, N/mm^2$

Shear reinforcement is not required.

1

However nominal shear reinforcement should be provided.

Provide stirrups of 2 legged 8 mm dia.

Step 4) Spacing of stirrups

$$Asv = 2\times\frac{\pi}{4}\times 8^2 = 100.53\, mm^2$$

Spacing of stirrups = Min. of following -

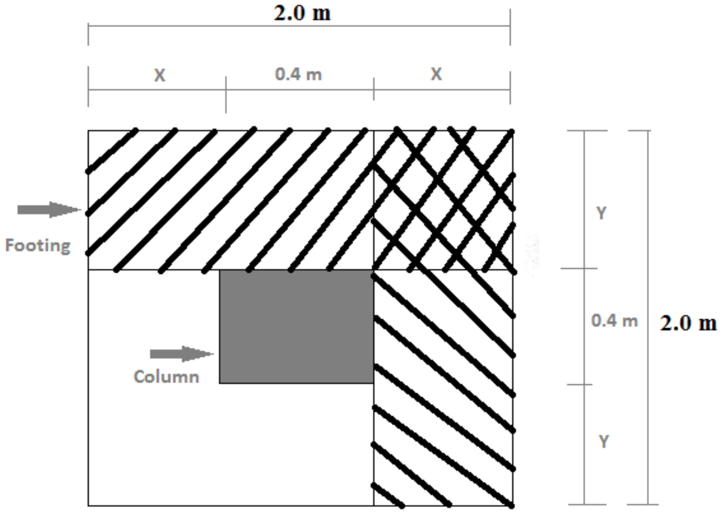
1

$$a)\, Sv = \frac{0.87\times f_y\times Asv}{0.4\times b} = \frac{0.87\times 415\times 100.53}{0.4\times 300} = 302.469\, mm$$

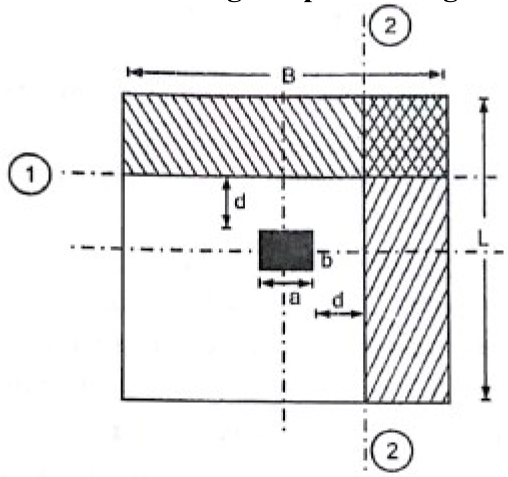
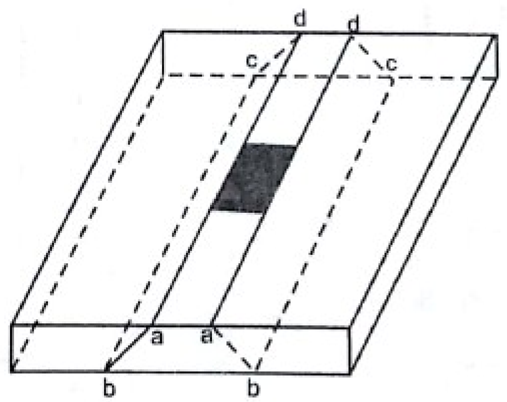
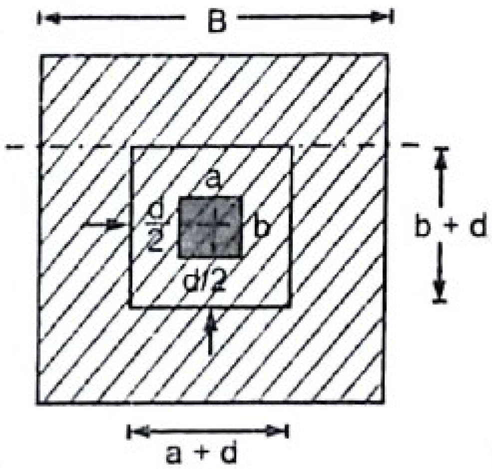
$$b)\, Sv = 0.75\times d = 0.75\times 660 = 495 mm$$

1

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 5	(b)	c) Sv=300 mm Hence, Sv = 300 mm Provide 8 mm dia. 2 legged vertical stirrups at 300 mm c/c	1	8
	(c)	**A square column size 400 X 400 mm carries axial load of 1000 kN. Determine size of square footing for column. If the SBC of soil is 200 kN/m², calculate depth of footing for B.M. criteria. Use M25 and Fe 415 steel.**		
	Ans.	Given: b = 400 mm P = 1000 kN SBC = 200 kN/m² f_{ck} = 25 N/mm² f_y = 415 N/mm² To find : Size of footing = ? Main steel = ?		
		Solution : Step 1 Ultimate S.B.C (q_u)=2×200 = 400 kN/m²	1	
		Step 2 Size of footing Assuming 5% as self wt.of footing $\text{Area of footing}(A_f)=\frac{(1.05\times P_u)}{q_u}=\frac{(1.05\times(1.5\times1000))}{400}$ $= 3.938\ m^2$ $L = \sqrt{A_f}$ $= \sqrt{3.938}$ = 1.984 m = 2.0 m (say) Adopt size 2.0 m×2.0 m	1	

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 5	(c)		1	
		x = y = $\frac{(2.0 - 0.4)}{2}$ = 0.8		
		Step 3 Upword soil pressure (p) $p = \frac{P_u}{(L \times B)} = \frac{1.5 \times 1000}{(2.0 \times 2.0)} = 375\ kN/m^2$	1	
		$M_x = M_y = 1 \times x \times p \times \frac{x}{2} = 1 \times 0.8 \times 375 \times \frac{0.8}{2}$ $= 120$ kN-m	1	
		$d_{req} = \sqrt{\frac{M_x}{(0.138 \times f_{ck} \times b)}} = \sqrt{\frac{120 \times 10^6}{(0.138 \times 25 \times 1000)}}$ $= 186.5$ mm = 190 mm (say)	1	
		adopt cover of 50 mm D = d + 50 = 190 + 50 = 240 mm Provide, D = 240 mm and d = 190 mm		
		Step 5 $Ast_x = Ast_y = \frac{0.5 \times fck}{fy} \times \left[1 - \sqrt{1 - \left(\frac{4.6 \times M_{ux}}{(fck \times bd^2)}\right)}\right] \times bd$		
		$= \frac{0.5 \times 25}{415} \times \left[1 - \sqrt{1 - \left(\frac{4.6 \times 120 \times 10^6}{(25 \times 1000 \times 190^2)}\right)}\right] \times 1000 \times 190$ $= 2156.443\ mm^2$	1	

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 5	(c)	using 16mm diameter $S_x = S_y = \frac{(1000 \times A\phi)}{Ast} = \frac{1000 \times \frac{\pi}{4} \times 16^2}{2156.443}$ $= 93.237 \text{ mm}$ $= 90$ mm c/c Provide 16 mm ϕ @ 90 mm c/c both way	1	8
Q.6		**Attempt any FOUR of the following :**		(16)
	(a)	**Write four IS specifications for the longitudinal reinforcement in columns.**		
	Ans.	**IS specifications for longitudinal reinforcement of an axially loaded short column:** i) Minimum diameter of bar in column = 12 mm ii) Minimum number of bars in circular column = 6 Nos iii) Cover of the column = 40 mm iv) Minimum and maximum steel in column Max % of steel = 6 % of gross cross sectional area of column Min % of steel = 0.8 % of gross cross sectional area of column	1 each	4
	(b)	**State the meaning of nominal cover. State purposes of providing cover to reinforcement.**		
	Ans.	**Nominal cover :** It is defined as the distance measured from the concrete surface to the nearest surface of the reinforcing bar.	2	
		Purposes of providing cover to reinforcement : 1) To prevent corrosion of steel . 2) To give necessary embedment to the reinforcing bar.	1 each	4
	(c)	**Calculate effective flange width for a T beam having span 8 m. The c/c distance between beams is 2.5 mm, width of web as 230 mm and flange depth as 120 mm. Supports are simple.**		
	Ans.	***(NOTE : c/c distance between beam should be 2.5 m instead of 2.5 mm)***		
		$l_o = 8000 + 230 = 8230 \text{ mm}$	1	
		$b_f = \left(\frac{l_o}{6} + b_w + (6 \times D_f)\right)$ or c/c distance between supports whichever is lesser	1	
		$= \left(\frac{8230}{6} + 230 + (6 \times 120)\right)$ or 2500 mm	1	4
		$= 2321.667$ mm or 2500 mm		
		$b_f = 2321.667$ mm	1	

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 6	(d)	**Sketch the critical sections used in the design of pad footings for bending and shears.**		
	Ans.	**Critical section used in the design of pad footings for bending :** 	2	
		Critical section used in the design of pad footings for shears :  One-way Shear Failure of Column Footing	1	
		 Two-way Action	1	4

Que. No.	Sub. Que.	Model Answer	Marks	Total Marks
Q. 6	(e)	**Calculate ultimate moment of resistance of the T beam having flange width 800 mm, slab thickness 120 mm, web thickness 300 mm and effective depth 500 mm to the centre of 4 – 20 mm Fe 415 bars using M25 concrete. (singly reinforced section is sufficient)**		
	Ans.	bf = 800 mm Df = 120 mm bw = 300 mm d = 500 mm $Ast = 4 \times \frac{\pi}{4} \times 20^2 = 1256.637\, mm^2$ f_{ck} = 25 N/mm^2 f_y = 415 N/mm^2		
		To find: M_u =?		
		Step 1 Find x_u $0.36 \times fck \times b_f \times x_u = 0.87 \times fy \times Ast$ $0.36 \times 25 \times 800 \times x_u = 0.87 \times 415 \times 1256.637$ $x_u = 63.015\, mm < D_f = 120\, mm$	1	
		Step 2 Find x_{umax} $x_{umax} = 0.48 \times d$ for Fe 415 $= 0.48 \times 500$ $= 240\, mm$	1	
		$\therefore$ As $x_u < x_{umax}$ section is under reinforced	1	
		Step 3 Find M_u $M_u = T_u \times a$ $= 0.87 \times fy \times Ast \times (d - 0.42 \times x_u)$ $= 0.87 \times 415 \times 1256.637 \times (500 - 0.42 \times 63.015)$ $= 214.846 \times 10^6$ N-mm $\boxed{Mu = 214.846\ kN\text{-}m}$	1	4