Model Answer: Winter 2017

Subject: Design of RCC Structures **Sub. Code: 17604**

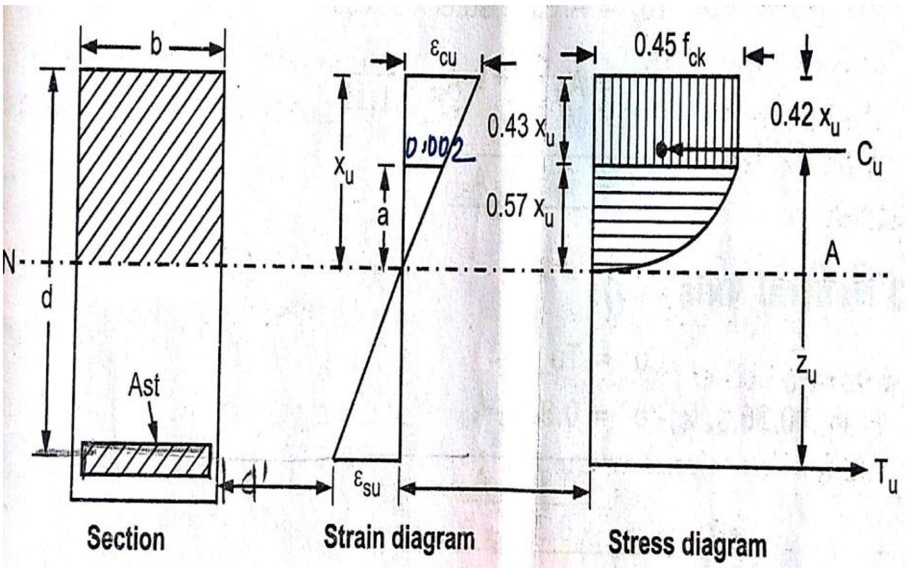
Important Instructions to examiners:

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 Answers	Marks	Total Marks
Q.1	**(A)**	**Attempt any THREE of the following:**		**(12)**
	(a)	**Define 'Characteristic load' and 'characteristic strength' of material.**		
		i) Characteristic load		
		Characteristic load is that value of load which has 95% probability of not being exceeded during the service life time of the structure.	**2**	
		ii) characteristic strength		**4**
		Characteristic strength of a material is the value of the material below which not more than 5% of test results are expected to fail.	**2**	
	(b)	**Why over reinforced section are not provided in LSM?**		
	Ans.	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.	**1 each**	**4**
		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.		

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
1.	**(c)**	**State any two ductile detailing provision as per IS : 13920**		
	Ans.	Requirement for longitudinal reinforcement in flexural members: 1) The top as well as bottom reinforcement shall consist of at least two bars throughout the member length 2) The maximum steel ratio on any face at any section, shall not exceed $P_{max} = 0.025$ 3) The positive steel at a joint face must be at least equal to half the negative steel at that face. ***(NOTE : Any other members ductile detailing provisions should be considered)***	**2 each (any two)**	**4**
	(d)	**State two advantages and two disadvantages of prestressed concrete.**		
	Ans.	**Advantages of prestressed concrete.** 1. The use of high strength concrete and steel in prestressed members results in lighter and slender members which is not possible in RC members. 2. In fully prestressed members the member is free from tensile stresses under working loads, thus whole of the section is effective. 3. In prestressed members, dead loads may be counter-balanced by eccentric prestressing. 4. Prestressed concrete member possess better resistance to shear forces due to effect of compressive stresses presence or eccentric cable profile. 5. Use of high strength concrete and freedom from cracks, contribute to improve durability under aggressive environmental conditions. 6. Long span structures are possible so that saving in weight is significant & thus it will be economic.	**1 each (any two)**	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
1.	**(d)**	7. Factory products are possible. 8. Prestressed members are tested before use. 9. Prestressed concrete structure deflects appreciably before ultimate failure, thus giving ample warning before collapse. 10. Fatigue strength is better due to small variations in prestressing steel, recommended to dynamically loaded structures. **Disadvantages of Prestressed Concrete** 1. The availability of experienced builders is scanty. 2. Initial equipment cost is very high. 3. Availability of experienced engineers is scanty. 4. Prestressed sections are brittle. 5. Prestressed concrete sections are less fire resistant.	**1 each (any two)**	**4**
	(e)	**When minimum shear reinforcement is provided? State the equation use for minimum shear reinforcement giving meaning of terms used in it.**		
	Ans.	If Nominal shear stress (ζv) < Design shear strength of concrete (ζc), minimum shear reinforcement in form of stirrup shall be provided such that,	**2**	**4**
		$\frac{Asv}{(b \times Sv)} \geq 0.4/\ 0.87fy$ Where, A_{sv} = total cross section area of stirrups legs effective in shear S_v = stirrups spacing along the length of the member b = breadth of beam or web of flanged beam f_y= characteristic strength of stirrup reinforcement in N/mm^2 which shall not be taken greater than 415N/ mm^2.	**2**	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.1.	**(B)**	**Attempt any ONE:**		**(6)**
	(a)	**A rectangular beam 230 mm wide and 400mm effective depth is reinforced with 4 bars of 16 mm diameter on tension side. Calculate the ultimate moment of resistance if M20 grade concrete and F_e415 steel is used.**		
	Ans.	$A_{st} = 4 \times \frac{\pi}{4} \times (16)^2 = 804.25\ mm^2$		
		$X_u = \frac{0.87 f_y A_{st}}{0.36 f_{ck} b} = \frac{0.87 \times 415 \times 804.25}{0.36 \times 20 \times 230}$	1	
		$\boxed{X_u = 175.35\ mm}$	1	
		$X_{u\max} = 0.48d = 0.48 \times 400 = 192\ mm$	1	6
		$X_u = 175.35\ mm < X_{u\max} = 192\ mm$ *Hence*, section is under reinforced,	1	
		$M_u = 0.87 f_y . A_{st} .(d - 0.42 X_u)$	1	
		$M_u = 0.87 \times 415 \times 804.25 [400 - (0.42) \times (175.35)]$		
		$\boxed{M_u = 94.764 \times 10^6\ N-mm}$		
		$\boxed{M_u = 94.764\ kN-m}$	1	
	(b)	**Draw stress-strain diagram for singly reinforced beam in LSM. State the position of neutral axis in terms of 'd' for critical section and maximum moment of resistance in terms of b and d using assumption in LSM as per IS 456-2000.**		
	Ans.		3	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
1	(b)	As per IS:456-2000, values of neutral axis in terms of 'd' for critical section and max. Moment of resistance in terms of b & d are given in table.	3	6

Steel type	f_y (N/mm^2)	$X_{u\ lim}$	$M_{u\ lim}$
Mild steel	250	0.53 d	0.149 fck bd^2
F_e 415	415	0.48 d	0.138 fck bd^2
F_e 500	500	0.46 d	0.133 fck bd^2

2 **Attempt any TWO:** **(16)**

(a) **A Design a slab for hall 4 m x 10 m for residential building with following data :**
Live load = 2 kN/m^2 **, Floor finish =** 1 kN/m^2
Width of support =230 mm , M.F = 1.4
Main Steel 10 mm diameter bars of F_e415
Distribution steel 6 mm diameter bars of F_e250
Use M20 grade concrete. Also draw the reinforcement details
(No Checks)

Ans. Given:

l=4m LL=2 kN/m^2 FF = 1 kN/m^2

MF =1.4 f_{ck}=20N/mm^2, f_y=415N/mm^2

Step (1)

$$d=\frac{Span}{20\times MF}=\frac{4000}{20\times 1.4}=142.857 \text{ mm}$$

Assuming, 10mm ϕ bars and cover of 20 mm

$$D = d+c+\frac{\phi}{2}=142.857+20+\frac{10}{2}=167.857 \text{ mm}$$

Provide, D =170 mm

$$d = 1700 - 20 - \frac{10}{2} = 145 \text{ mm}$$ **1**

Step (2)

Effective span

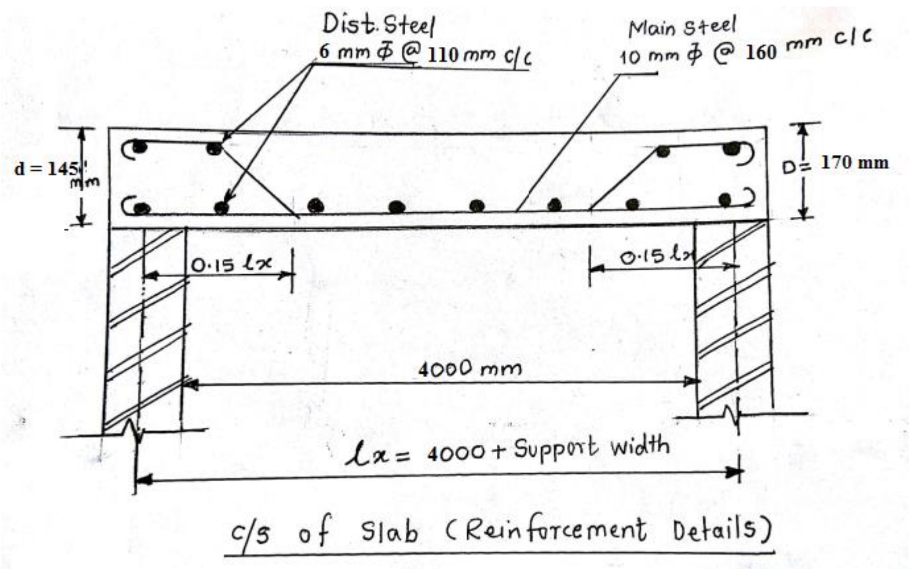
Min. of (a) & (b)

a) $l_e = l$+ d = 4000 + 145 = 4145 mm = 4.145m

b) $l_e = l$+ t =4000 + 230 = 4230 mm = 4.230m

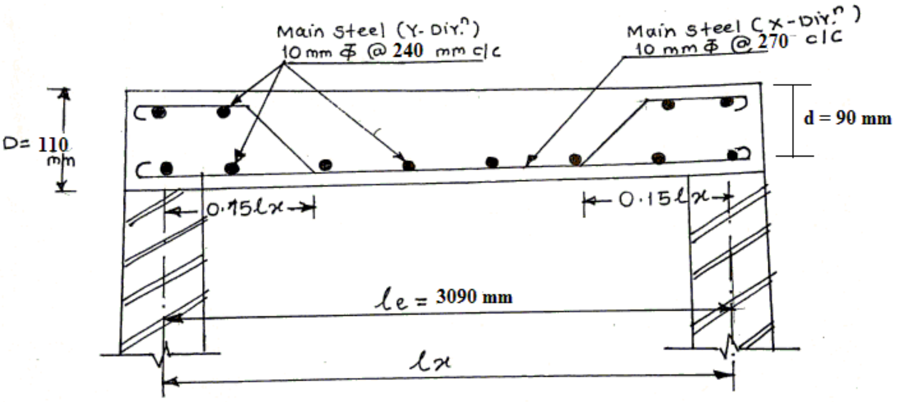
$l_e = 4.145m$ **1**

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
2.	**(a)**	Step (3) Load & B M calculation i) D.L. of slab = 0.170×1×1×25 = 4.25 kN/m ii) L.L. of slab = 2×1×1= 2.0 kN/m i) F.F. of slab = 1×1×1 = 1.0 kN/m Total load = 7.25 kN/m Factored load $(w_d)=1.5\times w$ $=1.5\times 7.25$ $= 10.875$ kN/m	**1**	
		$BM = Mu = \frac{w_d (l_e)^2}{8} = \frac{10.875\times(4.145)^2}{8}$ BM = Mu=23.355kN-m	**1**	
		Step (4) Check for depth $Mu_{max} = M_u$ $0.138 f_{ck} b (d_{reqd})^2 = 23.355\times 10^6$ $0.138\times 20\times 1000\times (d_{reqd})^2 = 23.355\times 10^6$ $(d_{reqd}) = 91.988mm < d = 145mm$ ....Ok	**1**	
		Step (5) Main steel and its spacing $A_{st} = \frac{0.5 f_{ck}}{f_y}\left[1-\sqrt{1-\frac{4.6\times Mu\times 10^6}{f_{ck} bd^2}}\right] bd$ $A_{st} = \frac{0.5\times 20}{415}\left[1-\sqrt{1-\frac{4.6\times 23.355\times 10^6}{20\times 1000\times (145)^2}}\right]\times 1000\times 145$ $A_{st} = 479.196 mm^2$ Spacing of bar Min. of a) $S_x = \frac{1000\times A\phi}{A_{st}} = \frac{1000\times \frac{\pi}{4}(10)^2}{479.196} = 163.899mm$ b) $S_x = 3d = 3\times 145 = 435mm$ c) $S_x = 300mm$ $S_x = 160mm$ c/c Provide 10 mm ϕ bars @ 160mm c/c along the shorter span	**1**	

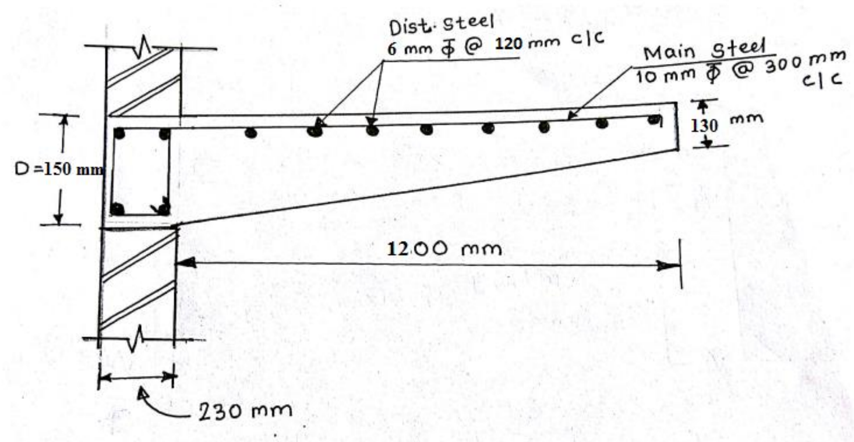
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
2	(a)	Step 6) Distribution steel and its spacing $A_{std} = \frac{0.15}{100} bD = \frac{0.15}{100} \times 1000 \times 170 = 255 mm^2$ Providing, 6mm ϕ bars, Spacing of bars is equal to min. of a) $S_y = \frac{1000 \times A\phi_d}{Ast_d} = \frac{1000 \times \frac{\pi}{4}(6)^2}{255} = 110.823mm$ b) $S_y = 5d = 5 \times 145 = 725mm$ c) $S_y = 450mm$ $S_y = 110.823mm$ c/c Provide 6 mm ϕ bars @ 110 mm c/c along the longer span	1	
		 c/s of Slab (Reinforcement Details)	1	8
	(b)	**Design a two way slab with following details:** **Size of room = 3.00 m X 4.50 m, LL =** 2 kN/m^2 **FF =** 1 kN/m^2**, Width of support =230 mm** **BM coefficient α_x = 0.104, α_y = 0.046** **Also draw the reinforcement details using 10 mm diameter bars of F_e 415. Use M20 grade concrete.**		
	Ans.	Given: $l_x = 3m$, $ly = 4.5m$, $f_{ck} = 20 N/mm^2$, $LL = 2\ kN/m^2$, $FF = 1\ kN/m^2$ $f_y = 415 N/mm^2$ $\alpha_x = 0.104$ $\alpha_y = 0.046$		

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
2	**(b)**	Step (1) Slab thickness, as l_x =3m < 3.5 m and LL = 2 kN/m^2 < 3 kN/m^2 *and Fe415 is used*. $D = \frac{l_x}{28} = \frac{3000}{28} = 107.142$ mm Provide, D = 110 mm Assuming, cover of 15 mm and providing 10mm ϕ bars $d = D - c - \frac{\phi}{2} = 110 - 15 - \frac{10}{2} = 90$ mm $\therefore$ Provide, D = 110 mm d = 90 mm	**1**	
		Step (2) Effective span $l_x = l_{xe} = l_x + d = 3000 + 90 = 3090$ mm $= 3.09$ m $l_y = l_{ye} = l_y + d = 4500 + 90 = 4590$ mm $= 4.59$	**1**	
		Step (3) Load & B M calculation i) D.L. of slab = 0.110 × 1 × 1 × 25 = 2.75 kN/m ii) L.L. of slab = 2×1×1= 2.0kN/m i) F.F. of slab = 1×1×1 = 1.0 kN/m Total load = 5.75 kN/m Factored load $(w_d) = 1.5 \times w$ $= 1.5 \times 5.75$ = 8.625 kN/m	**1**	
		BM calculations, $Mu_x = \alpha_x . w_d . (l_{xe})^2 = (0.104 \times 8.625 \times (3.09)^2)$ $Mu_x = 8.565$ kN-m $Mu_y = \alpha_y . w_d . (l_{xe})^2 = (0.046 \times 8.625 \times (3.09)^2)$ $Mu_x = 3.788$ kN-m	**1**	
		Step (4) Check for depth $Mu_{max} = M_{ux}$ $0.138 f_{ck} b (d_{reqd})^2 = 8.565 \times 10^6$ $(d_{reqd}) = 55.71$mm < d=90mm ....Ok	**1**	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
2	**(b)**	Step (5) Main steel and its spacing In X direction $A_{stx} = \frac{0.5f_{ck}}{f_y}\left[1-\sqrt{1-\frac{4.6\times M\mathit{ux}\times 10^6}{f_{ck}bd^2}}\right]bd$ $A_{st} = \frac{0.5\times 20}{415}\left[1-\sqrt{1-\frac{4.6\times 8.565\times 10^6}{20\times 1000\times (90)^2}}\right]\times 1000\times 90$ $A_{st} = 282.056\ mm^2$ Spacing of bar Min. of a) $S_x = \frac{1000\times A\phi}{A_{st}} = \frac{1000\times \frac{\pi}{4}(10)^2}{282.056} = 278.454mm$ b) $S_x = 3d = 3\times 90 = 270mm$ c) $S_x = 300mm$ $S_x = 270mm\ c/c$ Provide 10 mm ϕ bars @ 270 mm c/c	1	
		In Y direction $d' = d - \phi = 90 - 10 = 80mm$ $A_{sty} = \frac{0.5f_{ck}}{f_y}\left[1-\sqrt{1-\frac{4.6\times M\mathit{uy}\times 10^6}{f_{ck}bd'^2}}\right]bd'$ $A_{sty} = \frac{0.5\times 20}{415}\left[1-\sqrt{1-\frac{4.6\times 3.788\times 10^6}{20\times 1000\times (80)^2}}\right]\times 1000\times 80$ $A_{sty} = 136\ mm^2$ $A_{st\min} = \frac{0.12}{100}\times 1000\times 110 = 132mm^2$ $A_{sty} = 136mm^2 > A_{st\min}\ (132mm^2)$ Spacing of bar Min. of a) $S_y = \frac{1000\times A\phi}{A_{sty}} = \frac{1000\times \frac{\pi}{4}(10)^2}{136} = 577.498mm$ b) $S_y = 3d = 3\times 80 = 240mm$ c) $S_y = 300mm$ $S_y = 240mm\ c/c$ Provide 10 mm ϕ bars @ 240 mm c/c	1	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
2	**(b)**	 C/S of Slab (Reinforcement Details)	**1**	**8**
	(c)	**Design a cantilever chajja with following data:** **Span = 1.2 m, L.L. = 2 kN/m^2. Floor finish = 1 kN/m^2, Width of support = 230 x 400 mm beam. Draw the reinforcement details. Use 10 mm diameter bars Fe 415 and 6 mm diameter bars of Fe 250. Use M 20 grade concrete.**		
	Ans.	*Given* : Span= l=1.2m =1200mm, LL=2 kN/m^2, FF=1 kN/m^2 Support = 230×400 mm $f_{ck}=20\text{N/mm}^2$, $f_y=415\text{N/mm}^2$ *Step* 1) *Slab thickness* $d=\dfrac{Span}{7\times M.F.}$ *Assume,* M.F.1.4, cover=15 mm and $\phi=10mm$ $d=\dfrac{1200}{7\times1.4}=122.45mm$ $D=d+c+\dfrac{\phi}{2}=122.45+15+\dfrac{10}{2}=142.45mm$ *provide,* D=150mm, d=150-15-$\dfrac{10}{2}$=130mm D=150mm, d=130mm	**1**	
		Step (2) Effective span $l_e=l+\dfrac{d}{2}=1200+\dfrac{130}{2}=1265mm=1.265m$	**1**	

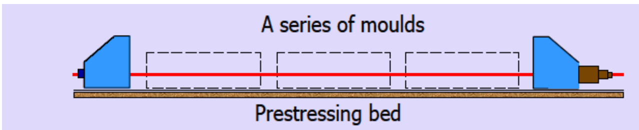
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
2	**(b)**	*Step* 3) Load cal. and BM i) D.L. of slab $=0.150\times1\times1\times25=3.75kN/m$ ii) L.L. of slab $=2\times1\times1=2kN/m$ iii) F.F. of slab $=1\times1\times1=1kN/m$ *Total* laod (w) = 6.75kN / m Factored load $w_d=1.5\times6.75=10.125kN/m$ $BM=M_u=\frac{(wd)l_e^2}{2}=\frac{10.125\times1.265^2}{2}=8.101kN-m$	**1** **1**	
		Step 4) *Check* for depth , $Mu_{max}=M_{ux}$ $0.138f_{ck}b\left(d_{reqd}\right)^2=8.101\times10^6$ $0.138\times20\times1000\times\left(d_{reqd}\right)^2=8.101\times10^6$ $\left(d_{reqd}\right)=54.176$ mm < d=130mm ....Ok	**1**	
		Step (5) Main steel and its spacing $A_{st}=\frac{0.5f_{ck}}{f_y}\left[1-\sqrt{1-\frac{4.6\times Mu\times10^6}{f_{ck}bd^2}}\right]bd$ $A_{st}=\frac{0.5\times20}{415}\left[1-\sqrt{1-\frac{4.6\times8.101\times10^6}{20\times1000\times(130)^2}}\right]\times1000\times130$ $A_{st}=177.722\ mm^2$ $A_{st\,min}=\frac{0.12}{100}\times1000\times130=156mm^2$ $A_{st}=177.722\ mm^2>A_{st\,min}\ (156mm^2)$ Spacing of bar Min. of a) $S_x=\frac{1000\times A\phi}{A_{st}}=\frac{1000\times\frac{\pi}{4}(10)^2}{177.722}=441.925mm$ b) $S_x=3d=3\times130=390mm$ c) $S_x=300mm$ $S_x=300mm$ c/c Provide 10 mm ϕ bars @ 300 mm c/c	 **1**	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
2	**(c)**	*Step* 6) $A_{st\,y} = A_{st\,min} = \frac{0.15}{100} \times 1000 \times 150 = 225mm^2$ Assuming, 6 mm ϕ bars Spacing of bar Min. of a) $S_y = \frac{1000 \times A\phi}{A_{st}} = \frac{1000 \times \frac{\pi}{4}(6)^2}{225}$ = 125.66mm b) S_y = 5d = 5×130 = 650mm c) S_y = 450mm S_y = 120 mm c/c Provide 6 mm ϕ bars @ 120 mm c/c  C/S of Chajja (Steel Details)	1 1	8
Q.3		**Attempt any FOUR:**		**(16)**
	(a)	**Find the moment of resistance of 'T' beam with following data: Df =120 mm, bf = 1200 mm, bw = 300 mm, d = 450 mm, Area of tension reinforcement = 2000 mm^2. Use M20 grade concrete and Fe 415 steel.**		
	Ans.	Step 1 Find x_u $0.36 \times fck \times b_f \times x_u = 0.87 \times fy \times Ast$ $0.36 \times 20 \times 1200 \times x_u = 0.87 \times 415 \times 2000$ $x_u = 83.57mm < D_f = 120mm$	1	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
3	(a)	Step 2 Find x_{umax} $x_{umax} = 0.479d$ for Fe415 $= 0.479 \times 450$ $= 215.55mm$ $\therefore$ As $x_u < x_{umax}$ section is under reinforced Step 3 Find M_u $M_u = T_u \times Z_u$ $= 0.87 \times fy \times Ast \times (d\text{-}0.42x_u)$ $= 0.87 \times 415 \times 2000 \times (450 - 0.42 \times 83.57)$ $= 299.59 \times 10^6$ N-mm Mu =299.59 kN-mm	1 1 1	4
	(b) Ans.	**A 'T' beam and 'L' beam are provided over a hall of 10m X 8m. Spacing of beam is 2.5 m c/c and span 8 m. Calculate the effective flange width of 'T' and 'L' beam. Width of rib = 230 mm, flange thickness = 120 mm.** ***Note : Answer may vary depending upon assumption of any one condition that is support thickness / width assumed or not, accordingly give appropriate marks.*** **Case : When width of support is assumed.** Step 1 Assuming effective span for the beam = c/c distance betwwen the supports and taking width of support = 230 mm $l_o = \frac{230}{2} + 8000 + \frac{230}{2}$ = 8230 mm Step 2 Effective flange width of 'T'beam bf $= \frac{l_0}{6} + b_w + 6D_f$ or c/c distance between supports --- whichever is small $= \frac{8230}{6} + 230 + 6 \times 120$ or 2500 mm ---- whichever is small = 2321.66 mm or 2500 mm ---- whichever is small b_f = 2321.66 mm	 1 1½	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
3	**(b)**	Step 3 Effective flange width of 'L' beam $b_f = \frac{l_0}{12} + b_w + 3D_f$ or 2500 mm --- whichever is small $= \frac{8230}{12} + 230 + (3 \times 120)$ or 2500 mm --- whichever is small = 1275.83 mm 2500 mm --- whichever is small b_f = 1275.83 mm	**1½**	**4**
		OR		
		Case : When width of support is not assumed.		
		Step 1 Assuming effective span for the beam = Shorter dimension of hall l_o = 8000	**1**	
		Step 2 Effective flange width of 'T'beam bf $= \frac{l_0}{6} + b_w + 6D_f$ or c/c distance between supports --- whichever is small $= \frac{8000}{6} + 230 + 6 \times 120$ or 2500 mm ---- whichever is small = 2283.33 mm or 2500 mm ---- whichever is small b_f = 2283.33 mm	**1½**	
		Step 3 Effective flange width of 'L' beam $b_f = \frac{l_0}{12} + b_w + 3D_f$ or 2500 mm --- whichever is small $= \frac{8000}{12} + 230 + (3 \times 120)$ or 2500 mm --- whichever is small = 1256.66 mm 2500 mm --- whichever is small b_f = 1256.66 mm	**1½**	**4**
	(c)	**Define 'Development length'. Also determine the development length for 16 mm diameter bar of Fe 415 in tension .Take τ_{bd} =1.4 N/mm^2 for a plain bar in tension.**		
	Ans.	**Development length:** It is the length required to develop the stress in the bar from zero to maximum by transfer of stress from concrete to steel.	**2**	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
3	(c)	Given data: ϕ = 16mm, fy=415 N/mm^2, τ_{bd} =1.4N/mm^2, bar is in tension $L_d = \dfrac{0.87\times fy\times\phi}{4\times\tau_{bd}'}$	1	
		$= \dfrac{0.87\times415\times16}{4\times1.6\times1.4}$ $\therefore \left(\begin{array}{l}\tau_{bd}' = 1.6\tau_{bd} \text{ ---- for deformed bar} \\ \text{the value of } \tau_{bd} \text{ increased by 60\%}\end{array}\right)$ = 644.73mm	1	4
	(d) Ans.	**Calculate the shear resisted by two bent up bars of Fe 415. Take α = 45^0.** ***Note : Answer may vary depending upon assumption of bar diameter, accordingly give appropriate marks.*** Assume, bar diameter = 20 mm Shear resisted by 2-bentup bars = Vusb Vusb = $0.87\times fy\times Asb\times\sin\alpha$	2	
		$= 0.87\times415\times\left(2\times\dfrac{\pi}{4}\times20^2\right)\times\sin45^0$ = 160410 N = 160.41 KN	2	4
	(e) Ans.	**Write any four assumptions in limit sate of collapse in compression as per IS 456- 2000**. i) Plane section normal to the axis remains plane after bending. ii) The maximum strain in concrete at the outermost compression fiber is taken as 0.0035 in bending. iii) For design purpose, the compressive strength of concrete in structure shall be assumed to be 0.67 times the characteristic strength. The partial safty factor Υ_m= 1.5 shall be applied in addition to this. iv) The tensile strength of concrete is ignored. v) The design stress in steel reinforcement is obtained from the strain at reinforcement level using idealized stress-strain curve for the types of reinforcement used. vi) For design purposes the partial safety factor Υ_m equal to 1.15 shall be applied. vii) The maximum compressive strain in concrete in axial compression is taken as 0.002. viii) The maximum compressive strain at the highly compressed extreme fiber in concrete subjected to axial compression and bending and when there is no tension on the section shall be 0.0035 minus 0.75 times the strain at the least compressed extreme fiber.	**1 each (any four)**	4

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q.4	**(A)**	**Attempt any THREE:**		**(12)**
	(a) Ans.	**State methods of prestressing and explain one of them in brief.**		
		i)Pre-Tensioning 1.Hoyer system	**1**	
		ii)Post-Tensioning 1. Freyssinet system 2. Magnel system 3. Leonhardt system 4. Lee-McCall system 5. Gifford-Udall system	**1**	
		Hoyer system: This system is generally used for mass production. The end abutments are kept sufficient distance apart, and several members are cast in a single line. The shuttering is provided at the sides and between the members. This system is also called the Long Line Method. The following figure is a schematic representation of the Hoyer system. The end abutments have to be sufficiently stiff and have good foundations.  Schematic representation of Hoyer system (***Note: Any one of the above method should be considered.)***	**2**	**4**

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
4	**(b)**	**Calculate the load carrying capacity of a column 400 mm X 400 mm is reinforced with 1% steel of Fe415. Use M20 grade concrete.**		
	Ans.	Step 1 Gross area, $A_g = 400 \times 400$ $= 160000 mm^2$	**1**	
		Step 2 Area of steel (A_{sc}) = 1% of Ag $= 0.001 \times 160000$ $= 1600\ mm^2$	**1**	
		Step 3 Area of concrete $(A_C) =$ Ag - A_{sc} $= 160000 - 1600$ $= 158400\ mm^2$	**1**	
		Step 4 Ultimate load carrying capacity (P_u) $P_u = (0.4 \times fck \times A_C) + (0.67 \times fy \times A_{sc})$ $= (0.4 \times 20 \times 158400) + (0.67 \times 415 \times 1600)$ $= 1712080N$ $= 1712.08\ kN$	**1**	**4**
	(c)	**State the critical combination of loads as per IS 456-2000. Also state the partial safety factors for concrete and steel for collapse.**		
	Ans.	IS 456-2000 recommends the following critical load combination of loads – i) Dead load + Live / Imposed load (DL + LL) ii) Dead load + Wind load (DL + WL) iii) Dead load + Live / Imposed load + Wind load (DL + LL + LL)	**2**	
		Partial safety factors for concrete and steel for collapse are - For concrete ----- $\Upsilon_{mc} = 1.5$	**1**	**4**
		For Steel ----- $\Upsilon_{ms} = 1.15$	**1**	
	(d)	**Define 'doubly reinforced section'. State any two condition in which doubly reinforced section is provided.**		
	Ans.	**Doubly Reinforced Section:** The R.C.C beam in which the reinforcement is provided on both tension and compression side is known as doubly reinforced beam.	**2**	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
4	**(d)**	Conditions where doubly reinforced section is provided are :- i) When the applied moment exceeds the moment resisting capacity of a singly reinforced beam. ii) When the dimension b and d of the section are restricted due to architectural, structural or constructional purposes. iii) When the sections are subjected to reversal of bending moment. e.g. piles, underground water tank etc. iv) In continuous T-beam where the portion of beam over middle support has to be designed as doubly reinforced. v) When the beams are subjected to eccentric loading, shocks or impact loads.	**1 each (any two)**	**4**
	(B)	**Attempt any ONE:**		**(6)**
	(a)	**Determine the ultimate moment of resistance of a doubly reinforced section 250 mm X 400 mm (effective), if Ast = 1500 mm^2, Asc = 600 mm^2. Assume M20 grade concrete and Fe 415 steel. fsc = 353 N/mm^2, d'/ d = 0.1, fcc = 0.45 fck.**		
	Ans.	Step 1 :Find $X_{umax} = 0.479d$ ------ for Fe415 $= 0.479 \times 400$ $X_{umax} = 191.6$ mm	1	
		Step 2 : Find actual X_u $fcc = 0.45 fck = 0.45 \times 20 = 9$ N/mm^2 $(0.36 fck.Xu.b) + (Asc(fsc - fcc)) = (0.87 fyAst)$	1	
		$(0.36 \times 20 \times Xu \times 250) + (600(353-9)) = (0.87 \times 9 \times 1500)$ $1800 Xu + 206400 = 541575$	1	
		$X_u = 186.20 mm$	1	
		$As, \quad Xu < X_{umax}$ $\quad$ *Beam is under reinforced section* Step 2 : Find Moment of Resistance M_u		
		$M_u = 0.36 \times f_{ck} \times b \times X_u (d - 0.42 X_u) + [(f_{sc} - f_{cc}) \times A_{sc} (d - d')]$	1	
		$M_u = 0.36 \times 20 \times 250 \times 186.20 (400 - (0.42 \times 186.20)) + (353 - 9) \times 600 (400 - 40)$ $M_u = 182.15 \times 10^6 N - mm$		
		$\boxed{M_u = 182.15 kN - m}$	1	6
		OR		
		Step 1 :Find $X_{umax} = 0.479d$ ------ for Fe415 $= 0.479 \times 400$ $X_{umax} = 191.6$ mm	1	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
4	**(a)**	Step 2 : Find actual Ast_2 $Ast_2 = \frac{(fsc - fcc)Asc}{0.87\,fy} = \frac{(353-9)\times 600}{0.87\times 415} = 571.665mm^2$	**1**	
		Step 3 : Find actual Ast_1 $Ast_1 = Ast - Ast_2 = 1500 - 571.665 = 928.335mm^2$	**1**	
		Step 4 : Find actual X_{u1} $X_{u1} = \frac{0.87\times fy \times Ast_1}{0.36\times fck \times b} = \frac{0.87\times 415\times 928.335}{0.36\times 20\times 250} = 186.20mm$ $X_{u1} < X_{umax}$ $\therefore$ Beam is under reinforced section.	**1**	
		Step 5 : Find Moment of Resistance M_u $fcc = 0.45\,fck = 0.45 \text{ x } 20 = 9 \text{ N/mm}^2$ $M_u = 0.36\times f_{ck}\times b\times X_u(d-0.42X_u) + [(f_{sc}-f_{cc})\times A_{sc}(d-d')]$	**1**	
		$M_u = 0.36\times 20\times 250\times 186.20(400-(0.42\times 186.20)) + (353-9)\times 600(400-40)$ $M_u = 182.15\times 10^6 N-mm$ $\boxed{M_u = 182.15kN-m}$	**1**	**6**
	(b)	**Determine the area of steel in tension and compression of a RCC rectangular beam 300 mm X 450 mm (effective). If it carries a factored moment of 240 kN-m, fcc = 0.45 fck, fsc = 353 N/ mm², d'/d = 0.1.**		
	Ans.	***Note : Answer may vary depending upon assumption of concrete and steel grade, accordingly give appropriate marks.***		
		$d'/d = 0.1 \quad \therefore d' = 45mm$ *Step* 1) To find x_{umax} $x_{u\max} = 0.479d$ $= 0.479\times 450$ $= 215.55mm Step$	**1**	
		2) To find M_{u_1} $M_{u_1} = M_{u\lim} = 0.138 f_{ck} bd^2$ $= 0.138\times 20\times 300\times 450^2$ $= 167.67\times 10^6 N-mm$	**1**	
		Step 3) To find A_{st_1} $Pt_{\lim} = 0.048 fck = 0.048\times 20 = 0.96\%$ ---- for M20 Concrete $A_{st_1} = \frac{Pt_{\lim}\times bd}{100} = \frac{0.96\times 300\times 450}{100}$ $\boxed{A_{st_1} = 1296mm^2}$	**1**	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
4	b)	*Step* 4) Balanced moment of resistance (Mu_2) $Mu_2 = Mu - Mu_1$ $= 240\times10^6 - 167.67\times10^6$ $= 72.33\times10^6\ N-mm$	1	6
		Step 5) To find Asc $fcc = 0.45 fck = 0.45\times20 = 9\ N/mm^2$ $fsc = 353\ N/mm^2$ $Mu_2 = Asc(fsc - fcc)(d-d')$ $72.33\times10^6 = Asc(353-9)\times(450-45)$ $Asc = 519.16 mm^2$	1	
		Step 6) *To find* Ast_2 $Cu_2 = Tu_2$ $Asc(fsc - fcc) = Ast_2\times0.87\times fy$ $519.16(353-9) = Ast_2\times0.87\times415$ $Ast_2 = 494.64 mm^2$ $\therefore Total\ Ast = Ast_1 + Ast_2$ $= 1296 + 494.64$ $= 1790.64 mm^2$	1	
Q.5		**Attempt any TWO :**		**(16)**
	(a)	**A doubly reinforced beam 230 mm X 500 mm overall. It carries a design moment of 280 kN-m. Cover on both sides is 40 mm. Use M20 grade concrete and Fe 415 steel. Calculate** **(i) Design moment of resistance for tension reinforcement.** **(ii) Compression steel.** **(iii) Total tensile reinforcement.** $f_{cc}=0.45f_{ck}$		

d'/d	**0.05**	**0.10**	**0.15**
f_{sc}**(N/mm²)**	**355**	**353**	**342**

Ans.

d = D - eff.cover = 500 - 40 = 460mm

$M_u = 280kN\text{-}m$

$M_u = M_{u1} + M_{u2}$

<table>
<tr><th>Que. No.</th><th>Sub. Que.</th><th>Model Answers</th><th>Marks</th><th>Total Marks</th></tr>
<tr><td>5</td><td>(a)</td><td>

$M_{u1} = M_{ulim} = 0.138 \times fck \times b \times d^2$
$= 0.138 \times 20 \times 230 \times 460^2$
$= 134.323 \times 10^6$ N-mm
$= 134.323$ kN-m
$M_{u2} = M_u - M_{u1} = 280 - 134.323 = 145.677$ kN-m
$X_{umax} = 0.48 \times d = 0.48 \times 460 = 220.8$mm
$\%Pt_{lim} = 0.048 \times f_{ck} = 0.048 \times 20 = 0.96\%$
$Ast_1 = \frac{\%Pt_{lim} \times b \times d}{100} = \frac{0.96 \times 230 \times 460}{100} = 1015.68\ mm^2$
$fcc = 0.45\,fck = 0.45 \times 20 = 9\,N/mm^2$
$\frac{d'}{d} = \frac{40}{460} = 0.087$

d'/d	0.05	0.087	0.10
fsc	355	x	353

$fsc = 355 - \frac{(0.037 \times 2)}{0.05} = 353.52 N/mm^2$
$M_{u2} = Asc \times (fsc - fcc) \times (d - d')$
$(145.677 \times 10^6) = Asc \times (353.52 - 9) \times (460 - 40)$
$Asc = 1006.76 mm^2$
$C_{u2} = T_{u2}$
$Asc \times (fsc - fcc) = Ast_2 \times 0.87 \times Fy$
$1006.76 \times (353.52 - 9) = Ast_2 \times 0.87 \times 415$
$Ast_2 = 960.667 mm^2$
$Ast = Ast_1 + Ast_2 = 1015.68 + 960.667$
$Ast = 1976.347 mm^2$

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<tr><td></td><td>(b)</td><td>

A simply supported beam of span 5 m carries a working udl of intensity 40 kN/m. Size of beam 350 mm X 500 mm (effective).It is reinforced with 4 bars of 20 mm diameter. Design 8 mm diameter 2 legged stirrups if one 20 mm diameter bar is bent up. Take ζc = 0.5 N/mm², ζc max = 2.8 N/mm². Use M20 grade concrete and Fe415 steel.

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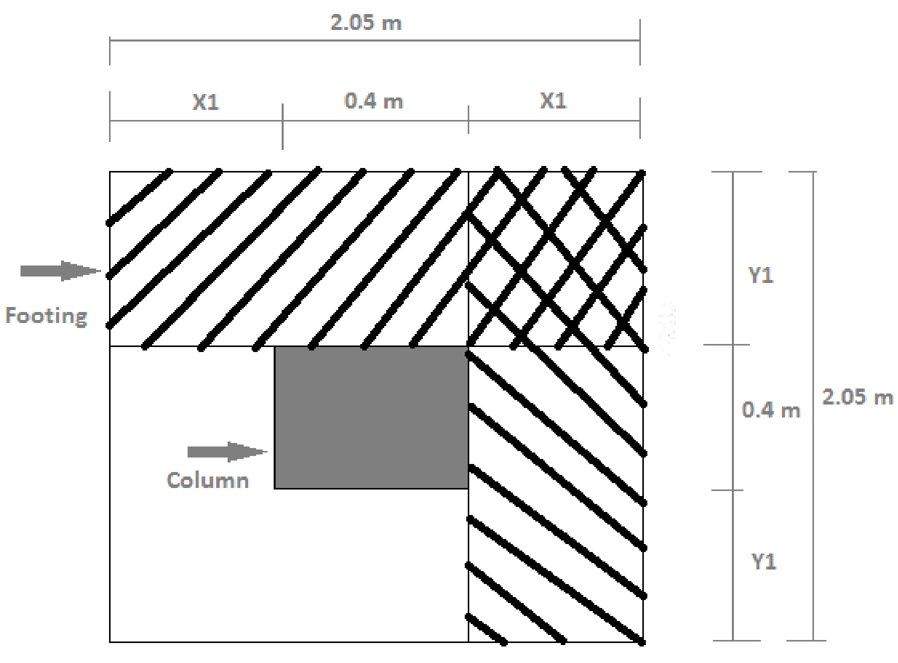
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
5	**Ans.**	*Given*: Simply supported beam, span (l) = 5m u.d.l(w) = 40 kN/m size of beam = 350X500mm (effective) $\tau_c = 0.5 N/mm^2$ $\tau_{c\max} = 2.8 N/mm^2$ $fck = 20\ N/mm^2$ $fy = 415\ N/mm^2$ stirrups = 2 legged-8mmϕ Factored load = $w \times 1.5$ $W_d = 40 \times 1.5 = 60$ kN/m Factored shear force(Vu) = $\frac{W_d \times l}{2} = \frac{60 \times 5}{2} = 150kN$ $\tau_v = \frac{v_u}{bd} = \frac{(150 \times 10^3)}{(350 \times 500)} = 0.857 N/mm^2 < \tau_{c\max} = 2.8 N/mm^2$ $\therefore$ Hence ok As one bar is bent up,only 3 bars will be available as tension reinforcement near to support $Ast = 3 \times \frac{\pi}{4} \times 20^2 = 942.477 mm^2$ $\%Pt = \frac{Ast}{bd} \times 100 = \frac{942.477}{(350 \times 500)} \times 100 = 0.538\%$ $\tau_c = 0.5 N/mm^2 < \tau_v = 0.857 N/mm^2$ $\therefore$ shear reinforcement is required shear force for which shear reinforcement is required $V_{us} = V_u - \tau_c \times b \times d = 150 \times 10^3 - 0.5 \times 350 \times 500$ $= 62.5 \times 10^3 = 62.5$ kN-m Area of bent up bar = $1 \times \frac{\pi}{4} \times 20^2 = 314.159 mm^2$ Assuming bar is bent at 45^0 V_{usb} = shear resisted by bent up bar $= 0.87 \times fy \times Asb \times \sin 45 = 0.87 \times 415 \times 314.159 \times \sin 45$ $= 80.205 \times 10^3 N = 80.205kN$	 **1** **1** **1** **1** **1** **1**	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
5	(b)	According to code, $V_{usb} < \frac{V_{us}}{2}$ $80.205kN < \frac{62.5}{2} = 31.2kN$ $\therefore$ useful contribution of bent up bar =31.25kN only $\therefore$ *Shear* required to be resisted by vertical stirrups $V_{usv} = \frac{Vus}{2} = 62.5 = 31.25kN$ $\therefore$ Shear resisted by min stirrups $V_{usv_{min}} = 0.4bD = 0.4\times350\times500 = 70kN > V_{usv} = 31.25kN$ Minimum stirrups are sufficient	1	
		$Asv = 2\times\frac{\pi}{4}\times8^2 = 100.53\ mm^2$ $\text{Spacing } (s) = \frac{(0.87\times fy\times Asv)}{0.4\times b} = \frac{(0.87\times415\times100.53)}{0.4\times350}$ $= 259.25 \approx 250mm$ $\therefore \text{spacing}(s) < 300mm \text{ or } (0.75\times500=375mm)$ $\therefore$ provide, 8mm ϕ 2 – *legged* stirrups @ 250 mmc/c	1	8
	(c)	**Design RC column footing for an axially loaded square column 400 mm X 400 mm. It carries a factored load of 1600 kN. Safe bearing capacity of soil = 200 kN/m². Calculate the depth of footing from bending moment criteria only. (No shear check is required). Use M20 grade concrete and Fe415 steel.**		
	Ans.	***Note : Answer may vary depending upon assumption of self weight of footing, accordingly give appropriate marks.*** Step 1 Ultimate S.B.C $(q_u) = 2\times200$ $= 400kN/m^2$ Step 2 Size of footing Assuming 5% as self wt.of footing $\text{Area of footing}(A_f) = \frac{(1.05\times W_u)}{q_u} = \frac{(1.05\times1600)}{q_u}$ $= 4.2\ m^2$	1	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
5	(c)	$L = B = \sqrt{A_f}$ $= \sqrt{4.2}$ $= 2.049\ m \approx 2.05m$ Adopt size $2.05 \times 2.05m$	1	
		Step 3 Upword soil pressure (p) $p = \frac{W_u}{(L \times B)} = \frac{1600}{(2.05 \times 2.05)} = 380.73\ kN/m^2$	1	
		Step 4 Depth for flexure *Let* $x_1 = y_1$ = projection beyond column $= \frac{(2.05 - 0.4)}{2} = 0.825\ m$	1	
			1	
		$M_x = M_y = 1 \times x_1 \times p \times \frac{x_1}{2} = 1 \times 0.825 \times 380.73 \times \frac{0.825}{2}$ $= 129.56$ kN-m	1	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
5	**(c)**	$d_{req} = \sqrt{\frac{M_x}{(0.138 \times Fck \times b)}} = \sqrt{\frac{M_x}{(0.138 \times fck \times b)}}$ $= 216.67mm \approx 220mm$ adopt cover of 80 mm D = d + 80 = 220 + 80 = 300mm	**1**	
		Step 5 $Ast_x = Ast_y = \frac{0.5 \times fck}{fy} \times \left[1 - \sqrt{1 - \left(\frac{4.6 \times M_{ux}}{(fck \times bd^2)}\right)}\right] \times bd$ $= \frac{0.5 \times 20}{415} \times \left[1 - \sqrt{1 - \left(\frac{4.6 \times 129.56 \times 10^6}{(20 \times 1000 \times 220^2)}\right)}\right] \times 1000 \times 220$ $= 2014.78mm^2$ using 16mm diameter $S_x = S_y = \frac{(1000 \times A\phi)}{Ast} = \frac{1000 \times \frac{\pi}{4} \times 16^2}{2014.78}$ $= 99.79mm \approx 90mm$ c/c provide 16mm ϕ @ 90 mm c/c both way	**1**	**8**
Q.6		**Attempt any FOUR :**		**(16)**
	(a)	**T beam with following details:** **b_f = 1400 mm, b_w = 230 mm, d = 650 mm, D_f = 100 mm, Ast = 2600 mm^2. Check the neutral axis fall within the depth of the flange.**		
	Ans.	***Note : Answer may vary depending upon assumption of Concrete and steel grade, accordingly give appropriate marks.*** *Asuume M* 20 grade of concrete and *Fe*415 steel $X_u = \frac{(0.87 \times fy \times Ast)}{(0.36 \times fck \times b_f)}$	**2**	
		$= \frac{(0.87 \times 415 \times 2600)}{(0.36 \times 20 \times 1400)}$ $X_u = 93.12mm < D_f = 100mm$ $\therefore X_u < D_f$	**1**	
		As Depth of neutral axis (X_u) is less than depth of flange (D_f), neutral axis lies within the flange.	**1**	**4**

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
6	(b)	**State the IS specification for the beam.** **(i) Horizontal spacing between the tension bars** **(ii) Vertical spacing between the tension bars** **(iii) Cover** **(iv) Minimum reinforcement**		
	Ans.	**(i) Horizontal spacing between the tension bars** (a) Min. Horizantal spacing is maximum of below a) 5 mm more than thatnominal size of coarse aggregate b) Diameter of bar if diameter are equal c) Diameter of largest bar if diameter are unequal (b) Max.. Horizantal spacing Steel clear distance mild steel < 300mm Fe415 < 180mm Fe500 < 150 mm	**1**	
		(ii) Vertical spacing between the tension bars Where there are two or more row of bars the bars shall be vertically in line and the minimum vertical distance between the bars shall be - greater of below a) 15 mm b) two thirds the nominal size of aggregate c) maximum size of bars	**1**	
		(iii) Cover minimum cover is equal to = 25 mm against corrosion = diameter of bar against slippage	**1**	
		(iv) Minimum reinforcement minimum reinforcement given by formula - As/bd = 0.85/fy As = 0.85bd/fy````````````````	**1**	**4**

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
6	**(c)**	**Define T beam. State the situations where a flanged RCC section is preferred.**		
	Ans.	**T Beam:** When the slab or flange occurs on both sides of the beam, the resulting c/s resembles a 'T' beam and hence called T-beam.	**2**	
		Following are the situations where a flanged RCC section is preferred : i) When slab and beam are to be casted together. ii) When main reinforcement of the slab is to be kept parallel to the beam, transverse reinforcement is not less than 60% of the main reinforcement at mid span of the slab.	**2**	**4**
	(d)	**State the condition of minimum eccentricity for the design of RCC short column as per IS 456-2000.**		
	Ans.	Minimum eccentricity = Maximum of (a) and (b) (a) $e_{min} = \frac{L_0}{500} + \frac{D}{30}$ (b) e_{min} = 20 mm	**2** **2**	**4**
	(e)	**State the IS specification for the following:** **(i) Minimum diameter of bar in column.** **(ii) Minimum number of bars in circular column.** **(iii) Cover to the column.** **(iv) Minimum and maximum steel in column.**		
	Ans.	i) Minimum diameter of bar in column = 12mm ii) Minimum number of bars in circular column = 6 Nos iii) Cover of the column = 40mm 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** **1** **1** **1**	**4**