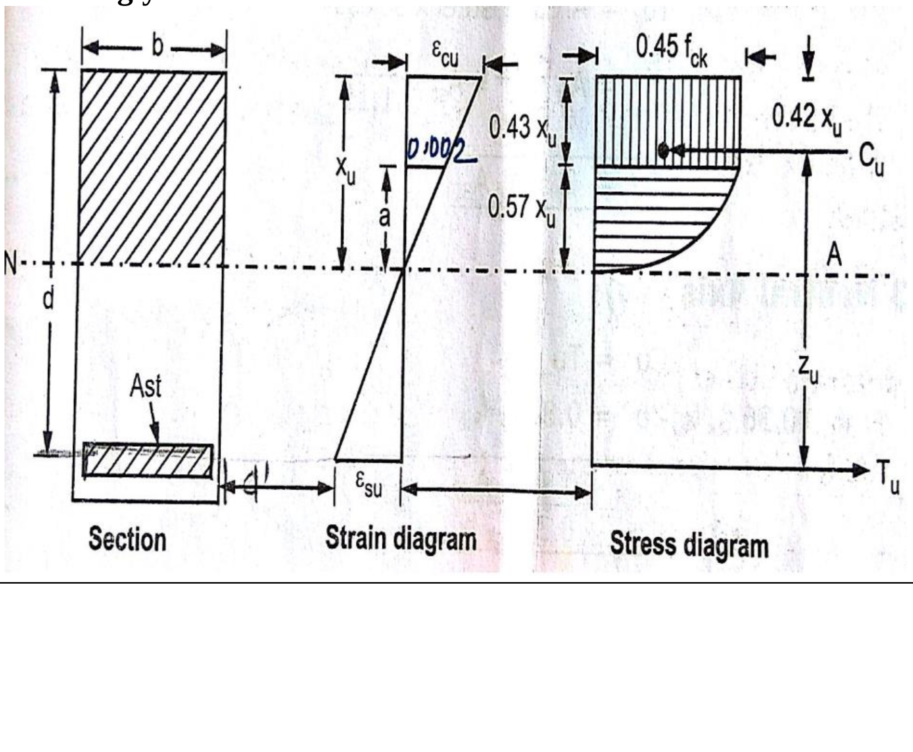
Model Answer: Summer 2018

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 Answers	Marks	Total Marks
Q. 1		**Attempt any THREE:**		12
	(a)	**State the meaning of partial safety factors for material strength and loads.**		
	Ans.	**Partial safety factor for material strength:** It is a strength reduction factor (greater than unity) when applied to the characteristic strength gives a strength known as design strength.	2	4
		Partial safety factor for load: It is a load enhancing factor (greater than unity) which when multiplied to characteristic load gives a load known as design load for which structure is to be designed.	2	
	(b)	**Draw a neat sketch showing strain diagram and stress diagram for a singly reinforced balanced section.**		
	Ans.		4	4

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 1	(c)	**State the functions of vertical stirrups provided in the beam.**		
	Ans.	Functions of vertical stirrups provided in the beam are as follows: i. To prevent sudden failure. ii. To prevent premature failure if the bond between main steel and concrete is lost. iii. To act as tie for holding the beam reinforcement. iv. To confine the concrete.	**1 each**	**4**
	(d)	**State the meaning of 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**	**4**
		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**	
	(e)	**Differentiate between pre-tensioning and post-tensioning.**		
	Ans.	(see table below)	**1 each**	**4**

Pre-tensioning	Post-tensioning
1.Tendons are stretched before concreting.	1.Tendons are stretched after setting of concrete.
2. It requires heavy abutments for anchoring steel wires.	2. Cables are anchored with the help of jacks. Cement grout is forced under pressure to fill the space in the ducts around tendons.
3. Losses are about 18%.	3. Losses are about 15%.
4. This method is suitable for mass production of small precast members. e.g. Railway sleepers.	4. This method is suitable for large members. e.g. Bridge construction.

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
	(B)	**Attempt any ONE:**		**6**
	(a)	**A R. C. beam 230 mm x 400 mm deep effective is reinforced with 1.02 % steel of grade Fe 415. Determine the position of NA and ultimate moment of resistance of the beam if f_{ck} = 25 N/mm^2.**		

Given:
b = 230 mm
d = 400 mm
Ast = 1.02 %
f_{ck} = 25 N/mm^2
f_y = 415 N/mm^2

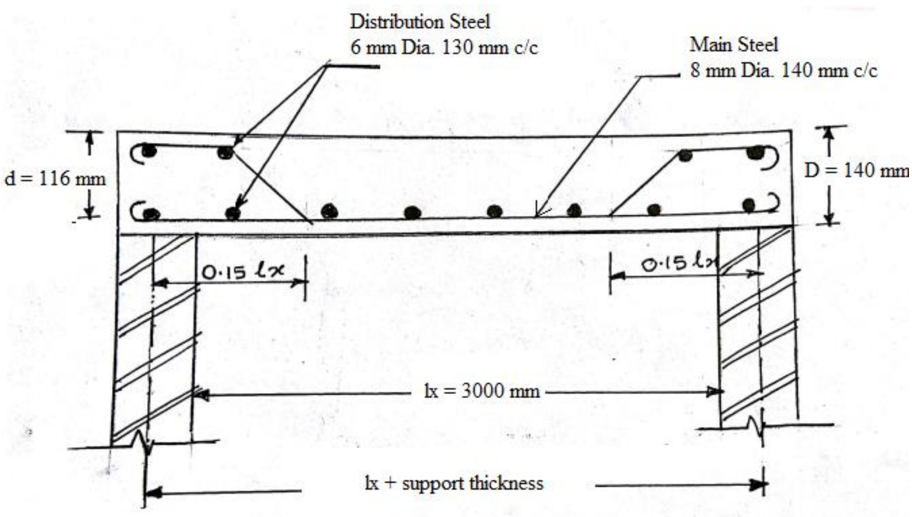
To find:
X_u = ?
M_u = ?

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 1		**Solution:**		
		$\%p_t = \frac{Ast}{b \times d} \times 100$		
		$1.02 = \frac{Ast}{230 \times 400} \times 100$	1	
		$A_{st} = 938.4\ mm^2$		
		$X_u = \frac{0.87 f_y A_{st}}{0.36 f_{ck} b} = \frac{0.87 \times 415 \times 938.4}{0.36 \times 25 \times 230}$	1	
		$\boxed{X_u = 163.676\ mm}$	1	6
		$X_{umax} = 0.48d = 0.48 \times 400 = 192\ mm$		
		$X_u = 163.676\ mm < X_{umax} = 192\ mm$	1	
		Hence, section is under reinforced,		
		$M_u = 0.87 f_y . A_{st} . (d - 0.42 X_u)$	1	
		$M_u = 0.87 \times 415 \times 938.4 \left[400 - (0.42) \times (163.676)\right]$		
		$\boxed{M_u = 112.233 \times 10^6 N\text{-}mm}$	1	
		$\boxed{M_u = 112.233\ kN\text{-}m}$		
	(b)	**A R. C. slab, 120 mm thick effective, has a simply supported effective span of 3.2 m. It is reinforced with 12 mm diameter bars at a spacing of 100 mm. Calculate the safe load (including self weight) the slab can carry if f_{ck} = 20 N/mm^2 and f_y = 415 N/mm^2.**		
	Ans.	Given: l = 3. 2 m = 3200 mm d = 120 mm ǿ = 12 mm Spacing of bars = 100 mm f_{ck} = 20 N/mm^2 f_y = 415 N/mm^2 To find: w = ?		
		Solution:		

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 1		Assume 1 m width of slab. b = 1000 mm Area of one 12 mm φ bar $A_\varphi = \frac{\pi}{4} \times 12^2 = 113.097\,mm^2$ $Spacing\,(S) = \frac{A_\varphi}{Ast} \times b$		
		$Ast = \frac{A_\varphi}{S} \times b = \frac{113.097}{100} \times 1000 = 1130.97\,mm^2$	1	
		$X_u = \frac{0.87 f_y A_{st}}{0.36 f_{ck} b} = \frac{0.87 \times 415 \times 1130.97}{0.36 \times 20 \times 1000}$	1	
		$X_u = 56.713$ mm	1	
		$X_{umax} = 0.48d = 0.48 \times 120 = 57.6$ mm $X_u = 56.713$ mm $< X_{umax} = 57.6$ mm	1	
		Hence, section is under reinforced, $M_u = 0.87 f_y . A_{st} .(d - 0.42 X_u)$ $M_u = 0.87 \times 415 \times 1130.97 [120 - (0.42) \times (56.713)]$		6
		$M_u = 39.274 \times 10^6$ N-mm	1	
		$M_u = 39.274$ kN-m But, $M_u = \frac{w_d \times l^2}{8}$ $39.274 = \frac{w_d \times 3.2^2}{8}$ $w_d = 30.683\,kN/m$ But, $w_d = w \times \gamma_f$ $w = \frac{w_d}{\gamma_f} = \frac{30.683}{1.5}$		
		$\boxed{w = 20.455\,kN/m}$	1	
Q. 2		**Attempt any TWO:**		16
	(a)	**A 3 m wide passage, supported on 230 mm thick side walls, carries a superimposed load of 3.75 kN/m² including floor finish. Design the suitable slab using M20 concrete and Fe 415 steel. Use 8 # and 6 ǿ bars. Take MF = 1.4. Apply the checks for maximum area of reinforcement, minimum area of reinforcement and spacing. Do not apply checks for shear and bond. Sketch the cross-section. Use effective cover – 20 mm.**		

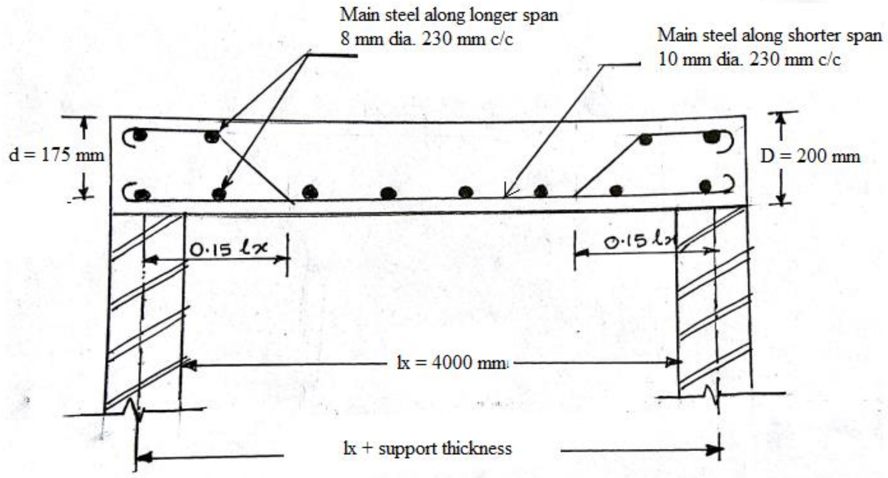
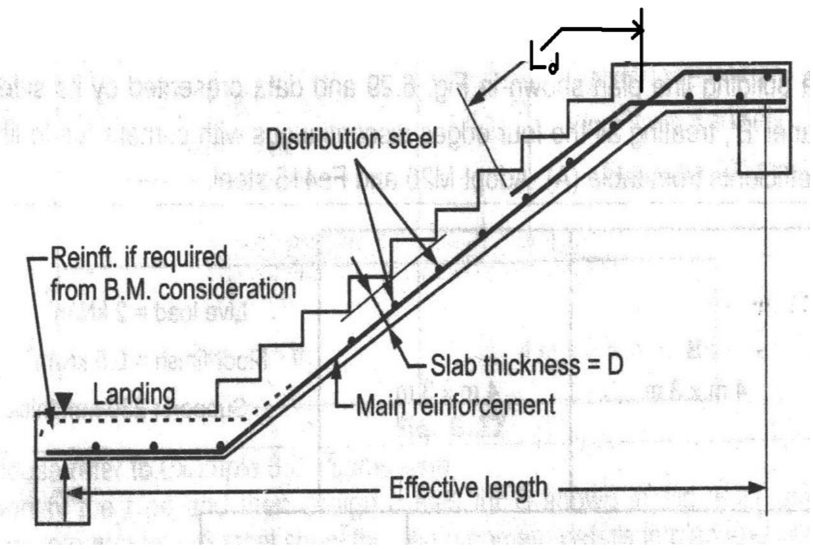
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 2	Ans.	Given: l = 3 m = 3000 mm t_s = 230 mm LL + FF = 3.75 kN/m^2 ϕ_x = 8 mm ϕ_y = 6 mm MF = 1.4 C = 20 mm f_{ck} = 20 N/mm^2 f_y = 415 N/mm^2 To find: D = ? Ast in both direction = ?		
		Solution: Step (1) $d=\frac{Span}{20\times MF}=\frac{3000}{20\times 1.4}=107.143$ mm $D = d+c+\frac{\varphi_x}{2}=107.143+20+\frac{8}{2}=131.143$ mm	1	
		Provide, D =140 mm $d = 140 - 20 - \frac{4}{2} = 116$ mm Step (2) Effective span Min. of (a) & (b) a) $l_e = l + d = 3000 + 116 = 3116$ mm = 3.116 m b) $l_e = l + t_s = 3000 + 230 = 3230$ mm = 3.230m $l_e = 3.116$ m	1	
		Step (3) Load & B M calculation i) D.L. of slab = $0.140\times1\times1\times25$ = 3.5 kN/m ii) L.L. + FF of slab = $3.75\times1\times1$ = 3.75 kN/m Total load = 7.25 kN/m	1	
		Factored load $(w_d) = 1.5\times w$ $= 1.5\times 7.25$ = 10.875 kN/m $BM = Mu = \frac{w_d (l_e)^2}{8} = \frac{10.875\times(3.116)^2}{8}$ **BM = Mu=13.199 kN-m**	1	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 2		Step (4) Check for depth $Mu_{max} = M_u$ $0.138 f_{ck} b \left(d_{reqd}\right)^2 = 13.199 \times 10^6$ $0.138 \times 20 \times 1000 \times \left(d_{reqd}\right)^2 = 13.199 \times 10^6$ $\left(d_{reqd}\right) = 69.153 \text{ mm} < d = 116 \text{ mm}$ ....Ok	1	
		Step (5) Maximum area of reinforcement $Ast_{max} = 0.04 \times b \times D = 0.04 \times 1000 \times 140 = 5600 \text{ mm}^2$ Minimum area of reinforcement $Ast_{min} = \frac{0.12}{100} bD = \frac{0.12}{100} \times 1000 \times 140 = 168 \text{ mm}^2$	1	
		Step (6) Main steel and its spacing $A_{st} = \frac{0.5 f_{ck}}{f_y}\left[1 - \sqrt{1 - \frac{4.6 \times Mu \times 10^6}{f_{ck} b d^2}}\right] bd$ $A_{st} = \frac{0.5 \times 20}{415}\left[1 - \sqrt{1 - \frac{4.6 \times 13.199 \times 10^6}{20 \times 1000 \times (116)^2}}\right] \times 1000 \times 116$ $A_{st} = 335.433 \text{ mm}^2$ Spacing of bar Min. of a) $S_x = \frac{1000 \times A\varphi_x}{A_{st}} = \frac{1000 \times \frac{\pi}{4}(8)^2}{335.433} = 149.853 \text{ mm}$ b) $S_x = 3d = 3 \times 116 = 348 \text{ mm}$ c) $S_x = 300 \text{mm}$ $S_x = 140 \text{ mm c/c}$ Provide 8 mm φ bars @ 140 mm c/c along the shorter span	1	
		Step (7) Distribution steel and its spacing $A_{std} = \frac{0.15}{100} bD = \frac{0.15}{100} \times 1000 \times 140 = 210 \text{ mm}^2$		

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 2		Spacing of bars is equal to min. of a) $S_y = \frac{1000 \times A\varphi_y}{Ast_d} = \frac{1000 \times \frac{\pi}{4}(6)^2}{210} = 134.640\,mm$ b) $S_y = 5d = 5 \times 116 = 580\,mm$ c) $S_y = 450mm$ $S_y = 130\,mm$ c/c Provide 6 mm φ bars @ 130 mm c/c along the longer span	1	8
		 c/s of Slab (Reinforcement Details)		
	(b)	**Design a two way slab for panel of effective size 5.6 m x 4 m simply supported on all four sides. It carries a live load of 3.5 kN/m² and a floor finish of 1 kN/m². Use M20 concrete, Fe 500 steel, MF of 1.2, 10 # bars and effective cover of 20 mm. Take α_x = 0.099 and α_y = 0.051. Do not apply check for shear and bond. Draw the cross section along shorter span.**		
	Ans.	Given: l_x = 4 m = 4000 mm l_y = 5.6 m = 5600 mm LL = 3.5 kN/m² LL = 1 kN/m² ϕ_x = 10 mm MF = 1.2 C = 20 mm α_x = 0.099 and α_y = 0.051 f_{ck} = 20 N/mm² f_y = 500 N/mm² To find: D = ? Ast in both direction = ?		

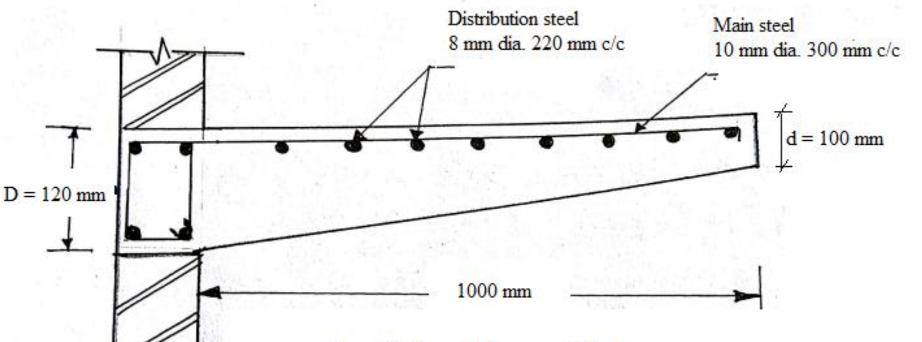
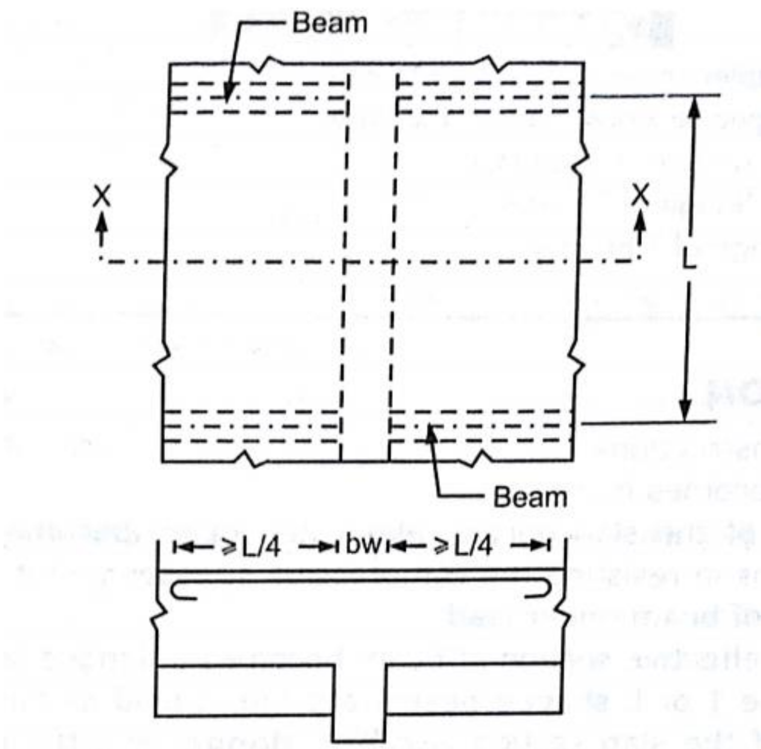
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 2		Step (1) Slab thickness, as $l_x = 4\,m > 3.5\,m$ and $LL = 3.5\,kN/m^2 > 3\,kN/m^2$ and Fe 500 is used. $d = \frac{Span}{20 \times MF} = \frac{4000}{20 \times 1.2} = 166.667$ mm $D = d + c + \frac{\varphi_x}{2} = 166.667 + 20 + \frac{10}{2} = 191.667$ mm Provide, D = 200 mm $d = 200 - 20 - \frac{10}{2} = 175$ mm	1	
		Step (2) Effective span $l_x = l_{xe} = l_x + d = 4000 + 175 = 4175\ mm = 4.175\,m$ $l_y = l_{ye} = l_y + d = 5600 + 175 = 5775\ mm = 5.775\,m$	1	
		Step (3) Load & B M calculation i) D.L. of slab = 0.2 × 1 × 1 × 25 = 5.0 kN/m ii) L.L. of slab = 3.5×1×1 = 3.5 kN/m i) F.F. of slab = 1×1×1 = 1.0 kN/m Total load = 9.5 kN/m Factored load $(w_d) = 1.5 \times w$ $= 1.5 \times 9.5$ $= 14.25$ kN/m	1	
		BM calculations, $Mu_x = \alpha_x . w_d . (l_{xe})^2 = (0.099 \times 14.25 \times (4.175)^2)$ $\boxed{Mu_x = 24.590\ kN\text{-}m}$ $Mu_y = \alpha_y . w_d . (l_{xe})^2 = (0.051 \times 14.25 \times (4.175)^2)$ $\boxed{Mu_y = 12.667\ kN\text{-}m}$	1	
		Step (4) Check for depth $Mu_{max} = M_{ux}$ $0.133 f_{ck} b (d_{reqd})^2 = 24.590 \times 10^6$ $(d_{reqd}) = 96.148\ mm < d = 175\ mm$ ....Ok	1	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 2		Step (5) Main steel and its spacing In X direction $A_{stx}=\frac{0.5f_{ck}}{f_y}\left[1-\sqrt{1-\frac{4.6\times Mux\times10^6}{f_{ck}bd^2}}\right]bd$ $A_{st}=\frac{0.5\times20}{500}\left[1-\sqrt{1-\frac{4.6\times24.590\times10^6}{20\times1000\times(175)^2}}\right]\times1000\times175$ $A_{st}=339.665\ mm^2$ Spacing of bar Min. of a) $S_x=\frac{1000\times A\varphi_x}{A_{st}}=\frac{1000\times\frac{\pi}{4}(10)^2}{339.665}=231.227\,mm$ b) $S_x=3d=3\times175=525\,mm$ c) $S_x=300mm$ $S_x=230\,mm$ c/c **Provide 10 mm φ bars @ 230 mm c/c** In Y direction $d'=d-\varphi_x=175-10=165\,mm$ $A_{sty}=\frac{0.5f_{ck}}{f_y}\left[1-\sqrt{1-\frac{4.6\times Muy\times10^6}{f_{ck}bd'^2}}\right]bd'$ $A_{sty}=\frac{0.5\times20}{500}\left[1-\sqrt{1-\frac{4.6\times12.667\times10^6}{20\times1000\times(165)^2}}\right]\times1000\times165$ $A_{sty}=181.565\,mm^2$ $A_{stmin}=\frac{0.12}{100}\times1000\times175=210\,mm^2$ $A_{sty}=181.565\,mm^2>A_{stmin}=210\,mm^2$ $A_{sty}=210\,mm^2$ Using 8 mm dia. bar Spacing of bar Min. of a) $S_y=\frac{1000\times A\varphi_y}{A_{sty}}=\frac{1000\times\frac{\pi}{4}(8)^2}{210}=239.359\,mm$ b) $S_y=3d'=3\times165=495\,mm$ c) $S_y=300mm$ $S_y=230mm$ c/c **Provide 8 mm φ bars @ 230 mm c/c**	1½ 1½	8

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 2		 c/s of Slab (Reinforcement Details)		
	(c)-(i)	**Draw the cross-section of a dog-legged staircase showing reinforcement details.**  **Fig. Dog legged staircase** ***(Note: 3 marks for sketch and 1 marks for labeling.)***	**4**	**4**
	c)-(ii)	**A cantilever slab of effective span 1.0 m carries a superimposed load of 1.5 kN/m^2 including floor finish. Calculate the depth and area of reinforcement. Use M20 concrete and mild steel. Take MF = 1.55.**		

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 2	Ans.	Given: l_e = 1 m = 1000 mm LL + FF = 1.5 kN/m^2 MF = 1.55 f_{ck} = 20 N/mm^2 f_y = 250 N/mm^2 To find: D = ? Ast in both direction = ? **Solution:** Step 1) Slab thickness $d=\frac{Span}{7\times M.F.}$ Assume, Cover =15 mm and φ_x =10 mm $d=\frac{1000}{7\times 1.55}=92.165\,mm$ $D=d+c+\frac{\varphi_x}{2}=92.165+15+\frac{10}{2}=112.165\,mm$ provide, D=120mm, $d=120-15-\frac{10}{2}=100\,mm$ $\boxed{D=120\,mm,\ d=100\,mm}$	1	
		Step (2) Effective span $l_e=1000+\frac{100}{2}=1050\,mm=1.05\,m$ Step 3) Load cal. and BM i) D.L. of slab =$0.120\times1\times1\times25=3.0$ kN/m ii) L.L.+ F.F. of slab =$1.5\times1\times1$ =1.5 kN/m Total laod (w) = 4.5kN / m Factored load $w_d=1.5\times4.5=6.75$ kN/m $BM=M_u=\frac{(wd)l_e^2}{2}=\frac{6.75\times1.05^2}{2}=3.72$ kN-m	1	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 2		Step 4) Check for depth , $Mu_{max} = M_{ux}$ $0.149 f_{ck} b \left(d_{reqd}\right)^2 = 3.72\times10^6$ $0.149\times20\times1000\times\left(d_{reqd}\right)^2 = 3.72\times10^6$ $\left(d_{reqd}\right) = 35.33$ mm < d=100 mm ....Ok Step (5) Main steel and its spacing $A_{st} = \frac{0.5f_{ck}}{f_y}\left[1-\sqrt{1-\frac{4.6\times Mu\times10^6}{f_{ck}bd^2}}\right]bd$ $A_{st} = \frac{0.5\times20}{250}\left[1-\sqrt{1-\frac{4.6\times3.72\times10^6}{20\times1000\times(100)^2}}\right]\times1000\times100$ $A_{st} = 174.945\ mm^2$ $A_{st\,min} = \frac{0.15}{100}\times1000\times100 = 225\ mm^2$ $A_{st} = 174.945\ mm^2 < A_{st\,min} = 225\ mm^2$ Hence, $A_{st} = 225\ mm^2$ Spacing of bar Min. of a) $S_x = \frac{1000\times A\varphi_x}{A_{st}} = \frac{1000\times\frac{\pi}{4}(10)^2}{225} = 349.06$ mm b) $S_x = 3d = 3\times100 = 300$ mm c) $S_x = 300$ mm $S_x = 300$ mm c/c Provide 10 mm φ bars @ 300 mm c/c Step 6) $Ast_y = Ast_{min} = \frac{0.15}{100}\times1000\times150 = 225 mm^2$ Assuming, 8 mm φ bars Spacing of bar Min. of a) $S_y = \frac{1000\times A\varphi_y}{A_{st}} = \frac{1000\times\frac{\pi}{4}(8)^2}{225} = 223.402$ mm b) $S_y = 5d = 5\times100 = 500$ mm c) $S_y = 450$ mm $S_y = 220$ mm c/c Provide 8 mm φ bars @ 220 mm c/c	1 1	4

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 2		 **c/s of Cantilever Slab**		
Q. 3		**Attempt any FOUR:**		**16**
	(a)	**State the necessary conditions for the beam to act as a flanged beam.**		
	Ans.	**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.  	**4**	**4**

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 3	(b)	**Write the expressions for effective flange width of T and L beams. State the meaning of each term.**		
	Ans.	**Expressions for effective flange width :**		
		i. For T beam $b_f = \frac{l_0}{6} + b_w + 6D_f$	1½	
		ii. For L beam $b_f = \frac{l_0}{12} + b_w + 3D_f$	1½	4
		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.	1	
	(c)	**State when and how minimum shear reinforcement is provided. Write the expression for minimum shear reinforcement giving the meaning of terms involved.**		
	Ans.	If Nominal shear stress (ζv) < Design shear strength of concrete (ζc), minimum shear reinforcement should be provided.	1	
		It is provided in form of stirrup.	1	
		Expression for minimum shear reinforcement: $\frac{Asv}{(b \times Sv)} \geq 0.4/\ 0.87fy$	1	4
		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.	1	
	(d)	**A 16 mm diameter bar of grade Fe 500 is used for resisting compression. Calculate the development length if the design bond stress is 1.2 N/mm^2 for plain bars in tension.**		

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 3	Ans.	Given data: φ = 16 mm, fy = 500 N/mm^2, τ_{bd}=1.2N/mm^2, bar is in compression $L_d = \frac{0.87 \times fy \times \varphi}{4 \times \tau_{bd}'}$	1	
		$= \frac{0.87 \times 500 \times 16}{4 \times 1.6 \times 1.25 \times 1.2}$ ($\tau_{bd}' = 1.6 \times 1.25 \times \tau_{bd}$ ---- for deformed bar the value of τ_{bd} increased by 60% and for bar in compression τ_{bd} shall be increased by 25 %.)	2	4
		$\boxed{L_d = 725\,mm}$	1	
	(e)	**Write IS specifications for longitudinal and transverse reinforcement of an axially loaded short column.**		
	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	2	
		IS specifications for transverse reinforcement of an axially loaded short column: i. IS specification for diameter of lateral ties: The diameter of the link should be maximum of the following: a) The diameter of the links should be at least one fourth of the largest diameter of the longitudinal steel. b) In any case the links should not be less than 6mm in diameter. ii. IS specification for pitch: The spacing of the link should not exceed the least of the following- a) The least lateral dimension of column. b) Sixteen times the diameter of the smallest longitudinal bar. c) 300 mm	2	4

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 4	(A)	**Attempt any THREE:**		12
	(a)	**Define characteristic strength and characteristic load.**		
	Ans.	**i. characteristic strength:** 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	4
		ii. 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	
	(b)	**Why doubly reinforced beam is provided? Write the expression for its moment of resistance if $X_u < X_{u\,max}$.**		
	Ans.	**Conditions where doubly reinforced section is provided are as follows:** 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 three)	4
		Expression for moment of resistance for Doubly reinforced beam if $X_u < X_{u\,max}$ $Mu = Mu_1 + Mu_2$ $Mu = (Tu_1 \times a_1) + (Cu_2 \times a_2)$ $Mu = \left[0.87 \times f_y \times Ast_1\left(d - 0.42 \times x_{u_1}\right)\right] + \left[\left(f_{sc} - f_{cc}\right)A_{sc}\left(d - d'\right)\right]$	1	
	(c)	**Enlist the losses in prestressed concrete. Explain any one in brief.**		
	Ans.	**Losses in prestressed concrete:** i. Due to elastic shortening of concrete ii. Due to creep of concrete iii. Due to shrinkage of concrete iv. Due to creep in steel v. Due to frictional loss vi. Due to slip at anchorages	½ each (any four)	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 4		i. Due to elastic shortening of concrete: As the prestress is transferred to concrete, the member shortens and prestressing steel also gets shortened along with it, resulting in loss of prestressed in steel. **OR** ii. Due to creep of concrete: Creep is a plastic deformation under constant stress. Concrete under the action of constant stress continues to deform with time, causing loss of prestress. **OR** iii. Due to shrinkage of concrete: During the process of drying and hardening, concrete undergoes contraction reducing the prestressing force. **OR** iv. Due to creep in steel - The loss of prestress due to creep of steel is the product of modulus of elasticity of steel and creep strain of steel. **OR** v. Due to frictional loss: It takes place only in post-tensioning system sue to relative movement between the tendon and the wall of the duct. **OR** vi. Due to slip at anchorages: The loss of prestress due to slip is due to slipping of wires during anchoring.	**2 each (any one)**	**4**
	(d)	**A square column of side 425 mm is reinforced with 8 bars of 20 mm diameter of grade Fe 500. If the grade of concrete is M25, calculate the safe load the column can carry.**		
	Ans.	Step 1 Gross area, $A_g = 425 \times 425$ $= 180625\,mm^2$ Step 2 Area of steel $(A_{sc}) = 8 \times \left(\frac{\pi}{4}\right) \times (20)^2$ $= 2513.274\ mm^2$ Step 3 Area of concrete $(A_C) = Ag - A_{sc}$ $= 180625 - 2513.274$ $= 178111.726\ mm^2$	**2**	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 4		Step 4 Ultimate load carrying capacity (P_u) $P_u = (0.4 \times fck \times A_C) + (0.67 \times fy \times A_{sc})$ $= (0.4 \times 25 \times 178111.726) + (0.67 \times 500 \times 2513.274)$ $= 2623064.05\ N$ $= 2623.06\ kN$	1	4
		Safe load carrying capacity (P) $P = \frac{Pu}{\gamma_f} = \frac{2623.06}{1.5}$ $\boxed{P = 1748.707\ kN}$	1	
	(B)	**Attempt any ONE:**		6
	(a)	**A doubly reinforced beam of size 250 mm x 400 mm is reinforced with 3, 20 # bars in tension and 2, 16 # bars in compression each at an effective cover of 40 mm. Calculate the ultimate moment of resistance if f_{ck} = 20 MPa, f_y = 415 MPa and f_{sc} = 353 MPa.**		
	Ans.	Given: b = 250 mm D = 400 mm C = 40 mm d = D – C = 360 mm $Ast = 3 \times \frac{\pi}{4} \times 20^2 = 942.477\ mm^2$ $Asc = 2 \times \frac{\pi}{4} \times 16^2 = 402.123\ mm^2$ f_{sc} = 353 N/mm² f_{ck} = 20 N/mm² f_y = 415 N/mm² To find: M_u = ? **Solution:**		

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 4		Step 1 :Find $X_{umax} = 0.48d$ ------ for Fe 415 $= 0.48 \times 360$ $X_{umax} = 172.8$ mm	1	6
		Step 2 : Find Ast_2 $f_{cc} = 0.45 \times f_{ck} = 0.45 \times 20 = 9$ N/mm^2 $Ast_2 = \frac{(f_{sc} - f_{cc}) \times A_{sc}}{0.87 \times f_y} = \frac{(353-9) \times 402.123}{0.87 \times 415}$ $Ast_2 = 383.133$ mm^2 $Ast_1 = Ast - Ast_2 = 942.477 - 383.133 = 559.344$ mm^2	1	
		Step 3 : Find Xu_1 $Xu_1 = \frac{0.87 \times f_y \times Ast_1}{0.36 \times f_{ck} \times b} = \frac{0.87 \times 415 \times 559.344}{0.36 \times 20 \times 250} = 112.195$ mm	1	
		Step 4 : Find type of section As $Xu_1 = 112.195$ mm $<$ $X_{umax} = 172.8$ mm Section is under-reinforced.	1	
		Step 5 : Find Moment of Resistance M_u $M_u = 0.87 \times f_y \times Ast_1 \times (d - 0.42Xu_1) + [(f_{sc} - f_{cc}) \times A_{sc} (d-d')]$ $M_u = 0.87 \times 415 \times 559.344 \times (360 - 0.42 \times 112.195) + [(353-9) \times 402.123 \times (360-40)]$	1	
		$M_u = 107.451 \times 10^6$ N-mm $\boxed{M_u = 107.451 \text{ kN-m}}$	1	
	(b)	**Calculate the area of steel reinforcements required for a doubly reinforced beam 250 mm x 450 mm over all, subjected to ultimate bending moment of 165 kN-m. Take f_{ck} = 20 MPa, f_y = 415 MPa, d' = 45 mm and f_{sc} = 353 MPa. The effective cover to tension steel is 45 mm.**		
	Ans.	Given: b = 250 mm D = 450 mm C = d' = 45 mm d = D – C = 405 mm Mu = 165 kNm f_{sc} = 353 N/mm^2 f_{ck} = 20 N/mm^2 f_y = 415 N/mm^2 To find: Ast = ? Asc = ?		

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 4		**Solution:** Step 1) To find x_{umax} $x_{umax} = 0.48d$ $= 0.48 \times 405$ $= 194.4\,mm$	1	
		Step 2) To find M_{u_1} $M_{u_1} = M_{ulim} = 0.138 f_{ck} bd^2$ $= 0.138 \times 20 \times 250 \times 405^2$ $= 113.177 \times 10^6$ N-mm	1	
		Step 3) To find A_{st_1} $Pt_{lim} = 0.048fck = 0.048 \times 20 = 0.96\%$ ---- for M20 Concrete $A_{st_1} = \frac{Pt_{lim} \times bd}{100} = \frac{0.96 \times 250 \times 405}{100}$ $\boxed{A_{st_1} = 972\,mm^2}$	1	6
		Step 4) Balanced moment of resistance (Mu_2) $Mu_2 = Mu - Mu_1$ $= 165 \times 10^6 - 113.177 \times 10^6$ $= 51.823 \times 10^6$ N-mm	1	
		Step 5) To find Asc $fcc = 0.45fck = 0.45 \times 20 = 9\ N/mm^2$ $fsc = 353\ N/mm^2$ $Mu_2 = Asc(fsc - fcc)(d - d')$ $51.823 \times 10^6 = Asc(353-9) \times (405-45)$ $\boxed{Asc = 418.467\,mm^2}$	1	
		Step 6) To find Ast_2 $Cu_2 = Tu_2$ $Asc(fsc - fcc) = Ast_2 \times 0.87 \times fy$ $418.467 \times (353-9) = Ast_2 \times 0.87 \times 415$ $Ast_2 = 398.706\,mm^2$ \Total $Ast = Ast_1 + Ast_2$ $= 972 + 398.706$ $\boxed{Ast = 1370.706\,mm^2}$	1	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 5		**Attempt any TWO:**		16
	(a)	**A simply supported beam of span 4 m carries a superimposed load of 50 kN/m. The size of beam is limited to 230 mm x 400 mm effective. Design the beam using concrete M20 and Fe 415 steel. Assume the cover of 40 mm to both reinforcements. Take f_{sc} = 353 N/mm^2 and unit weight of R.C.C. as 25 kN/m^3.**		
	Ans.	Given: b = 230 mm d = 400 mm C = d' = 40 mm w = 50 kN/m l = 4 m = 4000 mm P_{conc} = 25 kN/m^3 f_{sc} = 353 N/mm^2 f_{ck} = 20 N/mm^2 f_y = 415 N/mm^2 To find: Ast = ? Asc = ?		
		Solution: Step 1) To find Mu D = d + c = 400 + 40 = 440 mm = 0.44 m Total load acting on beam Self weigth of beam = $(b\times D\times\rho_{concrete})$=(0.23×0.44×25)=2.53 kN/m Superimposed load = 50 kN/m Total load (w) = 52.53 kN/m		
		Factored load $(w_d) = 1.5\times w = 1.5\times 52.53 = 78.795$ kN/m	1	
		$Mu = \frac{w_d\times l^2}{8} = \frac{78.795\times 4^2}{8} = 157.59$ kNm	1	
		Step 2) To find x_{umax} $x_{umax} = 0.48d$ $= 0.48\times 400$ $= 192$ mm	1	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 5		Step 3) To find M_{u_1} $M_{u_1} = M_{ulim} = 0.138 f_{ck} bd^2$ $= 0.138 \times 20 \times 230 \times 400^2$ $= 101.568 \times 10^6$ N-mm $M_{u_1} = 101.568$ kNm $< M_u = 157.59$ kNm Hence, Doubly reinforced beam is required.	1	
		Step 4) To find A_{st_1} $Pt_{lim} = 0.048fck = 0.048 \times 20 = 0.96\%$ ---- for M20 Concrete $A_{st_1} = \frac{Pt_{lim} \times bd}{100} = \frac{0.96 \times 230 \times 400}{100}$ $A_{st_1} = 883.2\ mm^2$	1	
		Step 5) Balanced moment of resistance (Mu_2) $Mu_2 = Mu - Mu_1$ $= 157.59 \times 10^6 - 101.568 \times 10^6$ $= 56.022 \times 10^6$ N-mm		8
		Step 6) To find Asc $fcc = 0.45fck = 0.45 \times 20 = 9\ N/mm^2$ $fsc = 353\ N/mm^2$ $Mu_2 = Asc(fsc - fcc)(d - d')$ $56.022 \times 10^6 = Asc(353-9) \times (400-40)$ $Asc = 452.374\ mm^2$	1	
		Step 7) To find Ast_2 $Cu_2 = Tu_2$ $Asc(fsc - fcc) = Ast_2 \times 0.87 \times fy$ $452.374 \times (353-9) = Ast_2 \times 0.87 \times 415$ $Ast_2 = 431.011\ mm^2$	1	
		Step 8) Total $Ast = Ast_1 + Ast_2$ $= 883.2 + 431.011$ $Ast = 1314.211\ mm^2$	1	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 5	(b)	**A beam 230 mm x 450 mm deep effective is reinforced with 4 – 16 # bars of grade Fe 415. The beam is subjected to a factored shear force of 147 kN. Design the shear reinforcement. Use two legged vertical stirrups of 8 # bars. Take ζ_{uc} = 0.57 N/mm^2.**		
	Ans.	Given: b = 230 mm d = 450 mm $Ast = 4 \times \frac{\pi}{4} \times (16)^2 = 804.248\, mm^2$ V_u = 147 kN ϕ = 8 mm diameter 2 legged ζ_{uc} = 0.57 N/mm^2 f_y = 415 N/mm^2 To find: Spacing of stirrups = ?		
		Solution : Step1) Nominal shear stress $\varsigma_v = \frac{V_u}{b \times d} = \frac{147 \times 10^3}{230 \times 450} = 1.42 N/mm^2$	1	
		Step 2) Shear strength of concrete $\varsigma_{uc} = 0.57\ N/mm^2 < \varsigma_v = 1.42 N/mm^2$ Shear reinforcement is required.	1	
		Step 3) Shear force for which shear reinforcement is required $V_{us} = V_u - (\varsigma_{uc} \times b \times d) = (147 \times 10^3) - (0.57 \times 230 \times 450)$ $V_{us} = 88.005\, kN$	1	
		Step 4) Shear force to be resisted by vertical stirrups Assuming bentup bars are not provided. Shear force to be resisted by vertical stirrups $V_{usv} = V_{us} = 88.005\, kN$	1	
		Step 5) Spacing of stirrups $Asv = 2 \times \frac{\pi}{4} \times 8^2 = 100.53\, mm^2$		

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 5		Spacing of stirrups = Min. of following - a) $Sv = \frac{0.87 \times f_y \times Asv \times d}{V_{usv}} = \frac{0.87 \times 415 \times 100.53 \times 450}{88.005 \times 10^3} = 185.596\,mm$ b) $Sv = \frac{0.87 \times f_y \times Asv}{0.4 \times b} = \frac{0.87 \times 415 \times 100.53}{0.4 \times 230} = 394.525\,mm$ c) $Sv = 0.75 \times d = 0.75 \times 450 = 337.5\,mm$ d) $Sv = 300\,mm$	3	8
		Hence, $Sv = 180\,mm$ Provide 8 mm dia. 2 legged vertical stirrups at 180 mm c/c	1	
	(c)	**Design a square column to carry an axial load of 1500 kN. The unsupported length of the column is 3.5 m. Use M20 concrete and 1 % Fe 500 steel for longitudinal reinforcement. Use MS bar for lateral ties. Apply the check for minimum eccentricity.**		
	Ans.	Given: l = lo = 3.5 m = 3500 mm P = 1500 kN Asc = 1 % of Ag f_{ck} = 20 N/mm^2 f_y = 500 N/mm^2 for main steel f_y = 415 N/mm^2 for transverse steel To find: Size of column = ? Main steel = ? Transverse steel = ? **Solution:**		
		Step 1) Factored axial load Pu = 1.5×P = 1.5×1500 = 2250 kN	1	
		Step 2) Size of column $Asc = \frac{1}{100} \times Ag = (0.01)Ag$ $Ac = Ag - Asc = (1)Ag - (0.01)Ag = (0.99)Ag$	1	
		Using formula- $Pu = (0.4 \times f_{ck} \times Ac) + (0.67 \times f_y \times Asc)$ $2250 \times 10^3 = (0.4 \times 20 \times 0.99 \times Ag) + (0.67 \times 500 \times 0.01 \times Ag)$ $Ag = 199.645 \times 10^3\,mm^2$	1	
		For square column $b = \sqrt{Ag} = \sqrt{199.645 \times 10^3} = 446.816\,mm$ Provide column of size 450 mm × 450 mm	1	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 5		Step 3) Check for eccentricity $e_{max} = 0.05 \times b = 0.05 \times 450 = 22.5\,mm$ $e_{min} = \left(\frac{l_o}{500} + \frac{b}{30}\right)$ or 20 mm whichever is larger $= \left(\frac{3500}{500} + \frac{450}{30}\right)$ or 20 mm whichever is larger $e_{min} = 22\,mm < e_{max} = 22.5\,mm$	1	
		Step 4) Main Steel $Asc = 0.01 \times Ag = 0.01 \times 450^2 = 2025\,mm^2$ Providing, 25 mm dia. bars $No.\ of\ bars = \frac{Asc}{A\varphi} = \frac{2025}{\frac{\pi}{4} \times 25^2} = 4.12$ Provide 6 bars of 25 mm dia. as main steel	1½	
		Step 5) Transverse steel i.e. links $Dia.\ of\ link = \frac{1}{4} \times \varphi$ or 6 mm whichever is greater $Dia.\ of\ link = \frac{1}{4} \times 25$ or 6 mm whichever is greater Dia. of link = 6.25 mm or 6 mm whichever is greater Provide 8 mm dia. links Spacing of links = Minimum of below a) S = b = 450 mm b) $S = 16 \times \varphi = 16 \times 25 = 400\,mm$ c) S = 300 mm S = 300 mm Provide 8 mm dia. links at 300 mm c/c	1½	

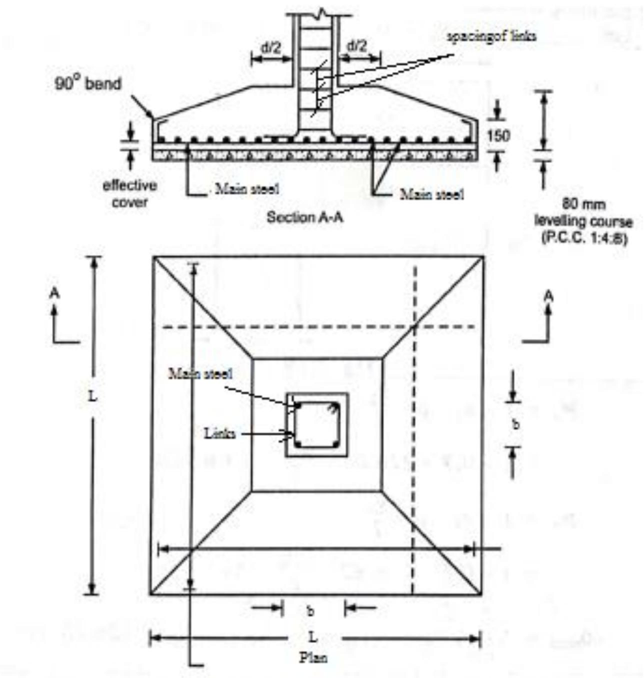
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 6		**Attempt any FOUR:**		16
	(a) Ans.	**Differentiate between balanced and under-reinforced sections.**		

	Balanced section	Under reinforced section
i) Strain	Strain in concrete and steel reaches to its maximum value at same time.	Strain in steel steel reaches to its maximum value first.
ii) Area of Steel	Equals to required for balanced section. Ast = Ast max.	Less compared to balanced section. Ast < Ast max.
iii) Neutral Axis	$Xu = Xu_{max}$	$Xu < Xu_{max}$
iv) Moment of resistance	$Mu = Mu_{max}$ $= q_{max}. f_{ck}. b . d^2$	$Mu = Tu.z$ $=0.87 fy Ast(d-0.42x_u)$

Marks: 1 each — Total: 4

(b) Ans.

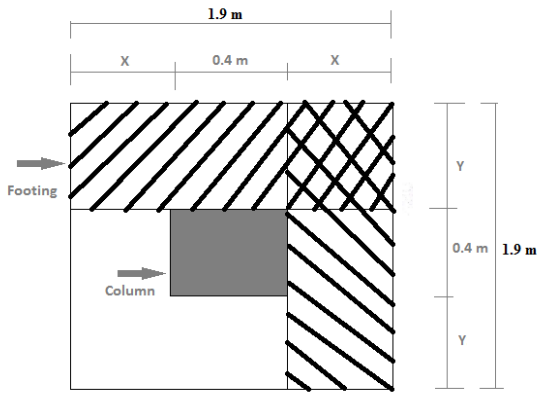
Draw the sketch showing the cross-section of an isolated square slopped footing. Show all the reinforcement details.



c/s of an Isolated Square Footing

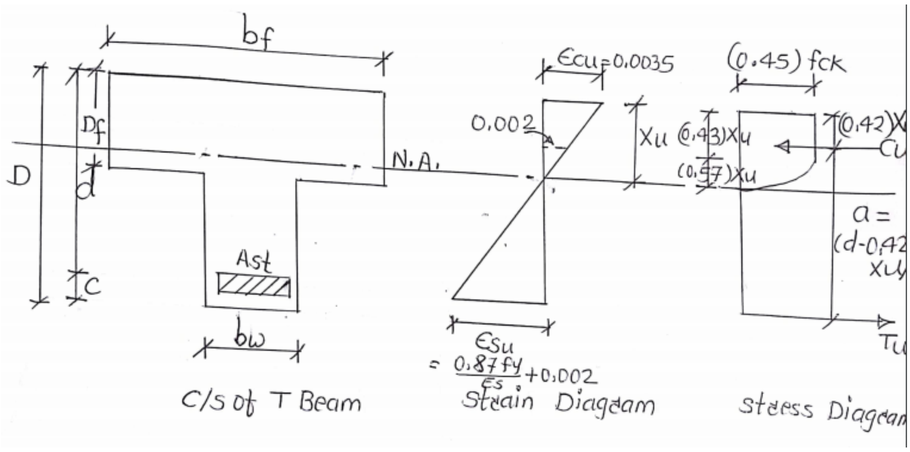
(Note : 3 marks for sketch and 1 for labeling).

Marks: 4 — Total: 4

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 6	(c)	**A column of size 400 mm x 400 mm carries an axial load of 1500 kN. Calculate the size and depth for B.M. of a square pad footing using M20 and Fe 500. The safe bearing capacity of soil is 350 kN/m^2.**		
	Ans.	Given: b = 400 mm; P = 1500 kN; SBC = 350 kN/m^2; f_{ck} = 20 N/mm^2; f_y = 500 N/mm^2. To find: Size of footing = ? Main steel = ?		
		Solution:		
		Step 1: Ultimate S.B.C $(q_u) = 2\times350 = 700$ kN/m^2		
		Step 2: Size of footing. Assuming 5% as self wt.of footing. $\text{Area of footing}(A_f) = \frac{(1.05\times P_u)}{q_u} = \frac{(1.05\times(1.5\times1500))}{700} = 3.375\ m^2$	1	
		$L = \sqrt{A_f} = \sqrt{3.375} = 1.837\ m \approx 1.9\ m$; **Adopt size 1.9 m × 1.9 m**		
			1	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 6		Step 3 Upword soil pressure (p) $p = \frac{P_u}{(L\times B)} = \frac{1.5\times1500}{(1.9\times1.9)} = 623.268\ kN/m^2$ $M_x = M_y = 1\times x_1\times p\times\frac{x_1}{2} = 1\times0.75\times623.268\times\frac{0.75}{2}$ $= 175.294$ kN-m		
		$d_{req} = \sqrt{\frac{M_x}{(0.133\times f_{ck}\times b)}} = \sqrt{\frac{175.294\times10^6}{(0.133\times20\times1000)}}$ $= 256.709\ mm \approx 260mm$ adopt cover of 50 mm D = d + 50 = 260 + 50 = 310 mm Provide, D = 310 mm and d = 260 mm	1	
		Step 5 $Ast_x = Ast_y = \frac{0.5\times fck}{fy}\times\left[1-\sqrt{1-\left(\frac{4.6\times M_{ux}}{(fck\times bd^2)}\right)}\right]\times bd$ $= \frac{0.5\times20}{500}\times\left[1-\sqrt{1-\left(\frac{4.6\times175.294\times10^6}{(20\times1000\times260^2)}\right)}\right]\times1000\times260$ $= 1896.524\ mm^2$		4
		using 16mm diameter $S_x = S_y = \frac{(1000\times A\varphi)}{Ast} = \frac{1000\times\frac{\pi}{4}\times16^2}{1896.524}$ $= 106.016\ mm \approx 100mm$ c/c Provide 16 mm φ @ 100 mm c/c both way	1	
	(d)	**Calculate the ultimate moment of resistance of a T-beam having – flange width 1250 mm, thickness of slab – 115 mm, effective depth – 600 mm, width of web – 300 mm and tension reinforcement consisting of 4 bars of 25 mm diameter of grade Fe 500. The grade of concrete is M20.**		

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 6	Ans.	Given : $b_f = 1250$ mm $D_f = 115$ mm $b_w = 300$ mm $d = 600$ mm $Ast = 4 \times \frac{\pi}{4} \times 25^2 = 1963.495\,mm^2$ $f_{ck} = 20\ N/mm^2$ $f_y = 500\ N/mm^2$ To find: $M_u = ?$ **Solution:** Step 1 Find x_u $0.36 \times fck \times b_f \times x_u = 0.87 \times fy \times Ast$ $0.36 \times 20 \times 1250 \times x_u = 0.87 \times 500 \times 1963.495$ $x_u = 94.902\,mm < D_f = 115\,mm$	1	
		Step 2 Find x_{umax} $x_{umax} = 0.46 \times d$ for Fe 500 $= 0.46 \times 600$ $= 276\,mm$ $\therefore$ As $x_u < x_{umax}$ section is under reinforced	1	4
		Step 3 Find M_u $M_u = T_u \times a$ $= 0.87 \times fy \times Ast \times (d - 0.42 \times x_u)$	1	
		$= 0.87 \times 500 \times 1963.495 \times (600 - 0.42 \times 94.902)$ $= 478.428 \times 10^6$ N-mm $\boxed{Mu = 478.428\ kN\text{-}m}$	1	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q. 6	(e) Ans.	**Draw the cross-section, strain diagram and stress diagram for a singly reinforced T beam with the neutral axis within the flange.** 	4	4