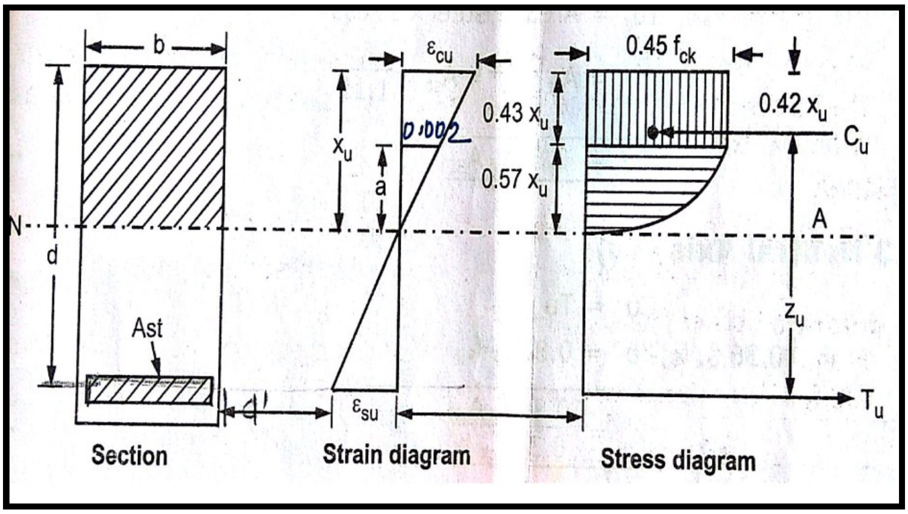
Model Answer: Summer 2017

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 :**		**12**
	a)	**Draw the stress block diagram for singly reinforced section.**		
	Ans.		**04**	**04**
		(Note: Two marks for sketch and two marks for labeling)		
	b)	**State any four functions of reinforcement in R.C. sections.**		
	Ans.	**Functions of reinforcement in R.C. sections:** 1. In case of slab, beams and wall of water tanks, reinforcement is mainly provided to carry direct or bending tensile stresses.		

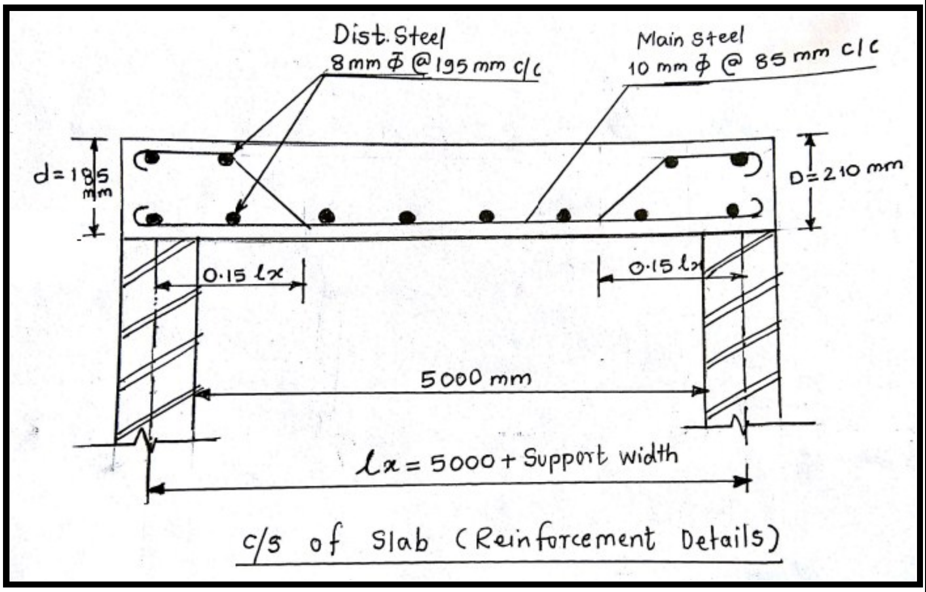
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
1		2. In case of columns the steel is provided to resist the direct compressive stress as well as bending stresses if any. 3. In case of beams stirrups are provided to resist the diagonal tension due to shear and hold the main steel in position. 4. The 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.	**01 mark each (any four)**	**04**
	c)	**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 than is possible with 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.	**01 mark each (any two)**	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
1		6. Long span structures are possible so that saving in weight is significant & thus it will be economic. 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.		**04**
		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.	**01 mark each (any two)**	
	d)	**State various forms of shear reinforcement in beams.**		
	Ans.	1. Vertical stirrups 2. Bent up bars along with stirrups, 3. Inclined stirrups	**04**	**04**
	e)	**State two ductile detailing provisions in 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)***	**02 marks each (any two)**	**04**

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
1	(B)	**Solve any ONE:**		06
	a)	**A beam 230mm x 450mm effective size carries a factored B. M. of 150 kN-m if concrete M20 and Steel grade Fe 500 are used, find area of steel.**		
	Ans.	$M_u = 150$ kN-m $= 150 \times 10^6$ N-mm $M_{umax} = (0.133) f_{ck} b d^2$ $= (0.133) \times 20 \times 230 \times (450)^2$ $= 123.889 \times 10^6$ N-mm $\boxed{M_{umax} = 123.889 kN-m}$	02	
		Since $M_u > M_{umax} = 123.889 kN-m$ *Section* is over reinforced. Hence desiging balanced section	02	
		For Fe 500, % $P_{tmax} = 0.038 f_{ck} = 0.038 \times 20 = 0.76\%$ But, % $P_{tmax} = \frac{A_{st}}{bd} \times 100$ $0.76 = \frac{A_{st}}{230 \times 450} \times 100$ $\boxed{A_{st} = 786.6 \text{ mm}^2}$	02	06
	b)	**Find moment of resistance if steel provided is 6 bars of 12 mm diameter in a beam 300 mm x 500 mm effective. Concrete M20 and. Steel Fe 500 are used.**		
	Ans.	$A_{st} = 6 \times \frac{\pi}{4} \times (12)^2 = 678.584\ mm^2$ $X_u = \frac{0.87 f_y A_{st}}{0.36 f_{ck} b} = \frac{0.87 \times 500 \times 678.584}{0.36 \times 20 \times 300}$ $\boxed{X_u = 136.659\ mm}$	02	
		$X_{u\max} = 0.46d = 0.46 \times 500 = 230\ mm$ $X_u = 136.659\ mm < X_{u\max} = 230\ mm$	02	
		Hence, section is under reinforced, $M_u = 0.87 f_y . A_{st} . (d - 0.42 X_u)$ $M_u = 0.87 \times 500 \times 678.584 [500 - (0.42) \times (136.659)]$ $\boxed{M_u = 130.649 \times 10^6\ N-mm}$ $\boxed{M_u = 130.649\ kN-m}$	02	06

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
2.		**Solve any TWO:**		**16**
	a)	**Design a one-way slab with following data span = 5.0 m, Live load = 4.5 kN/m², Floor finish = 1 kN/m². Concrete M 20 and steel Fe 415, M.F. = 1.4. Sketch c/s of slab showing reinforcement details.**		
	Ans.	Given: l=2m LL=4.5 kN/m² FF = 1 kN/m² MF =1.4 f_{ck}=20N/mm², f_y=415N/mm² Step (1) $d=\frac{Span}{20\times MF}=\frac{5000}{20\times1.4}=178.571$ mm Assuming, 10mm ϕ bars and cover of 20 mm $D = d+c+\frac{\phi}{2}=178.571+20+\frac{10}{2}=203.571$ mm Provide, D =210 mm $d = 210 - 20 - \frac{10}{2} = 185$ mm	02	
		Step (2) Effective span $l_e = l$+d=5000+185=5185 mm=5.185m	01	
		Step (3) Load & B M calculation i) D.L. of slab = 0.210×1×1×25 = 5.25 kN/m ii) L.L. of slab = 4.5×1×1= 4.5 kN/m i) F.F. of slab = 1×1×1×25 = 1.0 kN/m Total load = 10.75 kN/m	01	
		Factored load (w_d)=1.5×w =1.5×10.75 = 16.125 kN/m $BM = Mu=\frac{w_d(l_e)^2}{8}=\frac{16.125\times(5.185)^2}{8}$ BM = Mu=54.188kN-m	01	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
2		Step (4) Check for depth $Mu_{max} = M_u$ $0.138 f_{ck} b \left(d_{reqd}\right)^2 = 54.188 \times 10^6$ $0.138 \times 20 \times 1000 \times \left(d_{reqd}\right)^2 = 54.188 \times 10^6$ $\left(d_{reqd}\right) = 140.118mm < d = 185mm$ ....Ok Step (5) Main steel and its spacing $A_{st} = \frac{0.5 f_{ck}}{f_y}\left[1 - \sqrt{1 - \frac{4.6 \times Mu \times 10^6}{f_{ck} bd^2}}\right] bd$ $A_{st} = \frac{0.5 \times 20}{415}\left[1 - \sqrt{1 - \frac{4.6 \times 54.188 \times 10^6}{20 \times 1000 \times (185)^2}}\right] \times 1000 \times 185$ $A_{st} = 903.164mm^2$ Spacing of bar Min. of a) $S_x = \frac{1000 \times A\phi}{A_{st}} = \frac{1000 \times \frac{\pi}{4}(10)^2}{903.164} = 86.960mm$ b) $S_x = 3d = 3 \times 185 = 555mm$ c) $S_x = 300mm$ $S_x = 85mm$ c/c Provide 10 mm ϕ bars @ 85mm c/c along the shorter span Step 6) Distribution steel and its spacing $A_{std} = \frac{0.12}{100} bD = \frac{0.12}{100} \times 1000 \times 210 = 252mm^2$ Assuming, 8mm φ bars, Spacing of bars is equal to min. of a) $S_y = \frac{1000 \times A\phi_d}{Ast_d} = \frac{1000 \times \frac{\pi}{4}(8)^2}{252} = 199.466mm$ b) $S_y = 5d = 5 \times 185 = 925mm$ c) $S_y = 450mm$ $S_y = 195mm$ c/c Provide 8 mm ϕ bars @ 195 mm c/c along the longer span	01 01	**08**

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
2			**01**	

(***Note: Answer may vary on assumption of cover diameter of the bar)***

b) **The effective dimensions of a slab panel are 4 m x 7 m. it carries super imposed loads of 4 kN / sqm. Design a suitable slab using. M20 and Fe 415 steel. Take M.F. = 1.25, α_x = 0.113 and α_y = 0.037. Find total depth D factored BM and reinforcement details using suitable bars. Sketch the c/s of slab along shorter span showing reinforcement details.**

Ans.

Given: l_x =4m LL=4 kN/m^2 FF = 1 kN/m^2

MF=1.25 f_{ck} =20N/mm^2, f_y = 415N/mm^2

$\alpha_x = 0.113$ $\alpha_y = 0.037$

Step (1)

Slab thickness,

LL= 4 kN/m^2 > 3 kN/m^2 and

l_x = 4m > 3.5 m

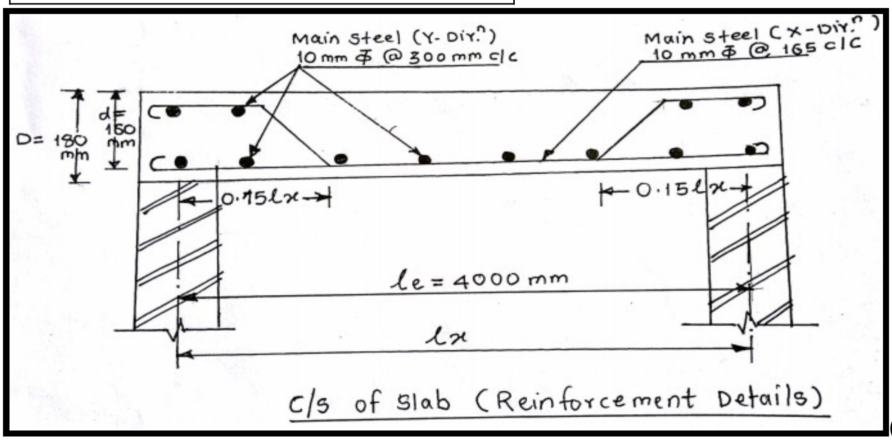
$$d = \frac{\text{Span}}{20\times MF} = \frac{4000}{20\times 1.4} = 160 \text{ mm}$$

Assuming, 10mm ϕ bars and cover of 15 mm

$$D = d + c + \frac{\phi}{2} = 160 + 15 + \frac{10}{2} = 180 \text{ mm}$$

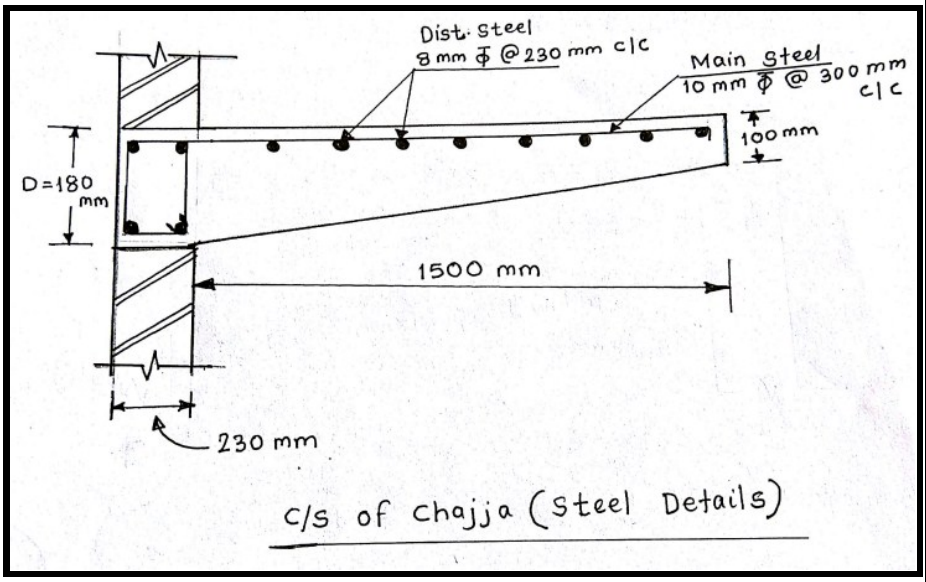
$\therefore$ Provide, D = 180 mm d = 160 mm **02**

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
2		Step (2) Effective span $l_x = l_{xe}$ = 4 m = 4000 mm $l_y = l_{ye}$ = 7 m = 7000 mm (As given diamensions are effective diamentions of slab panel)	**01**	
		(3)Load & B M calculation i) D.L. of slab = 0.180 × 1 × 1 × 25 = 4.5 kN/m ii) L.L. of slab = 4×1×1= 4 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×w =1.5×9.5 = 14.25kN/m	**01**	
		BM calculations, $Mu_x = \alpha_x . w_d . (l_{xe})^2 = (0.113 \times 14.25 \times (4)^2)$ $\boxed{Mu_x = 25.764 kN\text{-}m}$ $Mu_y = \alpha_y . w_d . (l_{xe})^2 = (0.037 \times 14.25 \times (4)^2)$ $\boxed{Mu_x = 8.436 kN\text{-}m}$	**01**	**08**
		Step (4) Check for depth $Mu_{max} = M_{ux}$ $0.138 f_{ck} b \left(d_{reqd}\right)^2 = 25.764 \times 10^6$ $\left(d_{reqd}\right) = 96.616mm < d = 160mm$ ....Ok		
		Step (5) Main steel and its spacing In X direction $A_{stx} = \frac{0.5 f_{ck}}{f_y}\left[1 - \sqrt{1 - \frac{4.6 \times Mu \times 10^6}{f_{ck} bd^2}}\right] bd$ $A_{st} = \frac{0.5 \times 20}{415}\left[1 - \sqrt{1 - \frac{4.6 \times 25.764 \times 10^6}{20 \times 1000 \times (160)^2}}\right] \times 1000 \times 160$ $A_{st} = 475.541\ mm^2$	**01**	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
2		Spacing of bar Min. of a) $S_x = \frac{1000 \times A\phi}{A_{st}} = \frac{1000 \times \frac{\pi}{4}(10)^2}{475.541} = 165.158mm$ b) $S_x = 3d = 3 \times 160 = 480mm$ c) $S_x = 300mm$ $S_x = 165mm$ c/c Provide 10 mm ϕ bars @ 165 mm c/c In Y direction $d' = d - \phi = 160 - 10 = 150mm$ $A_{sty} = \frac{0.5f_{ck}}{f_y}\left[1-\sqrt{1-\frac{4.6 \times Mu \times 10^6}{f_{ck}bd^2}}\right]bd$ $A_{st} = \frac{0.5 \times 20}{415}\left[1-\sqrt{1-\frac{4.6 \times 8.436 \times 10^6}{20 \times 1000 \times (150)^2}}\right] \times 1000 \times 150$ $A_{st} = 138.158\ mm^2$ $A_{st\min} = \frac{0.12}{100} \times 1000 \times 180 = 216mm^2$ $A_{sty} = 216mm^2$ Spacing of bar Min. of a) $S_y = \frac{1000 \times A\phi}{A_{sty}} = \frac{1000 \times \frac{\pi}{4}(10)^2}{216} = 363.61mm$ b) $S_y = 3d = 3 \times 150 = 450mm$ c) $S_y = 300mm$ $S_y = 300mm$ c/c Provide 10 mm ϕ bars @ 300 mm c/c  (*Note: Answer may vary on assumption of cover diameter of the bar)*	01 01	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
2	c) Ans.	**Design a cantilever chajja with following data: Span = 1.50 m, width = 2.0 m, L.L.= kN/m². Floor finish = 0.5 kN/m², support lintel = 230 x 300 mm concrete M 20, Fe 415 steel, sketch the c/s of chajja. Showing steel details.** *Given* : Span= l=1.5m=1500mm, Width= 2m=2000mm LL=1.5kN/m^2, FF=0.5kN/m^2 Support = 230×300 mm $f_{ck} = 20N/mm^2$, $f_y = 415N/mm^2$ *Step* 1) *Slab thickness* $d = \frac{Span}{7\times M.F.}$ *Assume*, M.F.1.4, cover=15 mm and $\phi = 10mm$ $d = \frac{1500}{7\times1.4} = 153.06mm$ $D = d + c + \frac{\phi}{2} = 153.06 + 15 + \frac{10}{2} = 173.06mm$ *provide*, D=180mm, d=180-15-$\frac{10}{2}$=160mm D=180mm, d=160mm Step (2) Effective span $l_e = l + \frac{d}{2} = 1580mm = 1.58m$ *Step* 3) Load cal. and BM i) D.L. of slab =$0.180\times1\times1\times25 = 4.5kN/m$ ii) L.L. of slab =$1.5\times1\times1 = 1.5kN/m$ iii) F.F. pf slab =$0.50\times1\times1 = 0.5kN/m$ *Total* laod (w) = 6.5 kN/m' Factored load $w_d = 1.5\times6.5 = 9.75kN/m$ $BM = M_u = \frac{(wd)l_e^2}{2} = \frac{9.75\times1.580^2}{2} = 12.169kN-m$ *Check* for depth , $Mu_{max} = M_{ux}$	 01 01 01 01	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
2		$0.138 f_{ck} b\left(d_{reqd}\right)^2 = 12\times10^6$ $0.138\times20\times1000\times\left(d_{reqd}\right)^2 = 12.169\times10^6$ $\left(d_{reqd}\right) = 66.400$ mm < d=160mm ....Ok Step (5) Main steel and its spacing $A_{st} = \frac{0.5 f_{ck}}{f_y}\left[1-\sqrt{1-\frac{4.6\times Mu\times10^6}{f_{ck}bd^2}}\right]bd$ $A_{st} = \frac{0.5\times20}{415}\left[1-\sqrt{1-\frac{4.6\times12.169\times10^6}{20\times1000\times(160)^2}}\right]\times1000\times160$ $A_{st} = 216.857\ mm^2$ $A_{st\,min} = \frac{0.12}{100}\times1000\times180 = 216 mm^2$ Spacing of bar Min. of a) $S_x = \frac{1000\times A\phi}{A_{st}} = \frac{1000\times\frac{\pi}{4}(10)^2}{216.857} = 362.173$mm b) $S_x = 3d = 3\times160 = 480$mm c) $S_x = 300$mm $S_x = 300$mm c/c Provide 10 mm ϕ bars @ 300 mm c/c *Step* 6) $A_{st\,y} = A_{st\,min} = \frac{0.12}{100}\times1000\times180 = 216 mm^2$ Assuming, 8 mm ϕ bars Spacing of bar Min. of a) $S_y = \frac{1000\times A\phi}{A_{st}} = \frac{1000\times\frac{\pi}{4}(8)^2}{216} = 232.710$mm b) $S_y = 5d = 3\times160 = 800$mm c) $S_y = 450$mm $S_y = 230$mm c/c Provide 8 mm ϕ bars @ 230 mm c/c	 **02** **01**	**08**

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
2		 *(Note: Answer may vary on assumption of cover diameter of the bar)*	01	
3.		**Attempt any FOUR :**		16
	a)	**Find the moment of resistance (M_r) of fec (T) beam with following data: D_f = 120 mm, b_f = 1500 mm, b_w = 300mm d = 450 mm, A_{sf} = 2200 mm^2, concrete M25, steel Fe 500.**		
	Ans.	**Given :** bf = 1500mm Df = 120mm bw = 300mm d =450mm Ast = 2200 mm^2 **To find M_u** **Step 1)** To find Xu=? (Assume Xu<Df) $X_u = \frac{0.87\ fy\ Ast}{0.36\ fck\ b_f}$ $X_u = \frac{0.87x500x2200}{0.36x25x1500}$ Xu=70.88 mm < Df =120 mm …….ok	01	

<table>
<tr><th>Que. No.</th><th>Sub. Que.</th><th>Model Answers</th><th>Marks</th><th>Total Marks</th></tr>
<tr><td>3</td><td></td><td>Step 2)
To find X_{umax}
$X_{umax} = 0.46 X d$
$= 0.46 X 450$
X_{umax}=207 mm
As, $X_u < X_{umax}$,

So, beam is under reinforced.

Step 3)

To find Mu=?
Mu = Tu x Zu
= 0.87 x fy x Ast (d -0.42 Xu)
= 0.87 x 500 x 2200 (450 -0.42 x 70.88)
$= 402.16 \times 10^6$ N-mm

Mu = 402.16 KN-m</td><td>01

01

01</td><td>04</td></tr>
<tr><td></td><td>b)

Ans.</td><td>State the conditions of formation of flanged beams & state effective flange width for T & L beam.
Is code recommends the following two provisions for beam spanning parallel to slab to act as a flanged beam,
1) Transverse reinforcement (perpendicular to beam) is required to be provided at the top in flanged portion for a length equal to L/4 on each side of beam. L= Span of slab.
2) Transverse reinforcement > 60% of main reinforcement at mid span of slab.
3) The slab shall cast integrally with the web or the web and slab shall be effectively bonded together in any other manner.

The effective width of the flange may be taken as following in no case greater than the width of the web plus half the sum of the clear distance to the adjacent beam on the either side.
a) For T beam
$b_f = \frac{Lo}{6} + b_w + 6 D_f$
b) For L beam
$b_f = \frac{Lo}{12} + b_w + 3D_f$</td><td>01

01

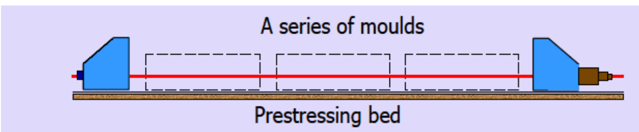
01

01</td><td>04</td></tr>
</table>

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
3		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.		
	c)	**Define development length & state factors affecting development length.**		
	Ans.	**Development Length:** Development length is defined as the length of the bar required on either side of the section to develop the required stress in steel at that section through bond. **OR** Development length is an embedded length of the bar required to develop the design stress in reinforcement at the critical section	**02**	
		Factors affecting development length: 1. Grade of steel. 2. Grade of concrete. 3. Diameter of bar. 4. Design bond stress.	**½ mark each**	
	d)	**Diameter of a steel bar is 20 mm, steel Fe 415 grade and design bond stress is 1.2 MPa for plain bars in tension, calculate the development length for bar inn compression.**		
	Ans.	Given: Φ = 20mm f_{ck} = 20 N/mm^2 f_y = 415N/mm^2 Bond stress, τ_{bd} =1.2 N/mm^2		

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
3		**Development length for bar in compression** $Ld = \frac{0.87 fy\ \phi}{4 \tau bd}$ For Fe 500 steel value of τ_{bd} shall be increased by 60% and for bar in compression, the value of bond stress for bar in tension shall be increased by 25% $Ld = \frac{0.87x415x20}{4x1.6x1.25x1.2}$ L_d = 752.1875 mm	02 02	04
	e) **Ans.**	**Design a rectangular column with following data:** **Factored load = 3500 kN, concrete M 20, Steel Fe 415, Unsupported length = 4.0 m. Assume 1 % steel.** ***(Note: Answer may vary according to shape of column assumed)*** Given: P_u = 3500 kN L = 4 m = 4000mm F_{ck} = 20 N/mm^2 F_y = 415 N/mm^2 **Step 1)** **To find Size of column** $P_u = (0.4 f_{ck}\ A_c) + (0.67\ f_y\ A_{sc})$ Assume 1% of steel in column Area of steel, $A_{sc} = 0.01\ A_g$ Area of concrete $A_c = A_g - A_{sc}$ $A_c = 0.99 A_g$ $3500x10^3 = (0.4x20x0.99A_g) + (0.67x415x0.01 A_g)$ $A_g = 327.087x10^3$ mm^2 Assume b = 400 mm	 01	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
3		**(Students may assume any other value of 'b' according the 'd' will changed)**		
		$D = \frac{Ag}{b} = \frac{327.087x10^3}{400}$ = 817.71 mm = 820 mm	**01**	**04**
		Step 2)		
		Check for minimum eccentricity		
		e_{min} = L/500 + D/30 OR 20mm whichever is greater		
		= 4000/500 + 820/30		
		e_{min} = 35.33 mm OR 20mm whichever is greater		
		e_{min} =35.33 mm		
		e_{max} = 0.05D		
		0.05D = 0.05 X 820 =41 mm		
		e_{min} 35.33mm < e_{max} 41 mm ....ok for minimum eccentricity.		
		Provide size of column = 400 mm x 820 mm		
		A_{sc} = 0.01 Ag		
		= 0.01 X 400 X 820	**01**	
		A_{sc} = 3282 mm^2		
		Provide 8 bars of 20 mm ϕ bar and 2 bars of 25 mm ϕ		
		A_{scprod}. = 8x314.15 + 2 x 490.87 = 3494.94 mm^2 > 3282 mm^2 .. ok		
		$\%Pt = \frac{3494.24}{400 \times 820} \times 100 = 1.06\%$		
		$\%Pt_{min}$ = 0.18%<%Pt =1.06<$\%Pt_{max}$ = 6%		
		Step 3)Lateral Ties		
		Diameter of ties = ¼ X diameter of longitudinal steel bar.		
		= ¼ X 25		
		= 6.25 mm		
		So, provide 8 mm dia. lateral ties.		
		Pitch should not be greater than		
		i) Least lateral dimensions of column i.e. 400mm.		
		ii) 16 x dia. of longitudinal steel =16 x ϕ =16 x 20 = 320 mm		
		iii) 300mm	**01**	
		(Select minimum of above values)		
		Therefore, provide lateral ties 8mm ϕ @ 300mm c/c.		

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
Q4	A)	**Attempt any THREE :**		12
	a)	**State methods of prestressing and explain in brief any one.**		
	Ans.	**i)Pre-Tensioning** 1.Hoyer system **ii)Post-Tensioning** 1. Freyssinet system 2. Magnel system 3. Leonhardt system 4. Lee-McCall system 5. Gifford-Udall system	02	04
		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 above method should be considered)***	02	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
4.	b)	**Calculate load carrying capacity of column 300 mm in diameter reinforced with 4- 16mm ϕ and 6-12mm ϕ bars use M20 concrete and Fe 415 steel.**		
	Ans.	Given data : Size of column = 230 x 230mm $A_{sc} = 4x\ (\pi/4)\ x\ (16)^2 + 6\ x\ (\pi/4)\ x\ (12)^2$ $= 804.24+678.58\ mm^2$ $=1482.82\ mm^2$ $f_{ck} = 20\ N/mm^2$ $f_y = 415\ N/mm^2$ To find, load carrying capacity of column, P		
		Step 1 : Gross area = Ag = $(\pi/4)\ x\ 300^2$ $Ag = 70685.83\ mm^2$	01	
		Step 2 : Area of steel, $A_{sc} = 1482.82\ mm^2$	01	04
		Step 3 : Area of concrete, $A_c = A_g - A_{sc}$ $A_c = 69203\ mm^2$	01	
		Step 4 : Ultimate load carrying capacity, P_u $P_u = [\ 0.4\ x\ f_{ck}\ x\ A_c\ ] + [\ 0.67\ x\ f_y\ x\ A_{sc}\ ]$ $= [\ 0.4\ x\ 20\ x\ 69203] + [\ 0.67\ x\ 415\ x\ 1482.82\ ]$ $P_u = 965.92\ x\ 10^3\ N = 965.92\ kN$	01	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
	c)	**Define:** **(i) Characteristic strength and** **(ii) Characteristic load.**		
	Ans.	**i) Characteristic Strength** Characteristic Strength means that value of the strength of the material below which not more than 5% of the test results are expected to fall.	**02**	**04**
		ii) Characteristic Load Characteristic Load means that value of load which has 95% probability of not being exceeded during the life of the structure.	**02**	
	d)	**State four situations where doubly reinforced section are preferred.**		
	Ans.	1) When the singly reinforced beams need considerable depth to resist large bending moment, it becomes necessary to provide doubly reinforced section. 2) When the size of rectangular beam cross-section is limited because of architectural reasons or practical reasons then it becomes necessary. 3) When the sections are subjected to reversal of bending moment. 4) When it is required to reduce the long-term deflection, it becomes necessary to provide doubly reinforced section. 5) When a beam is continuous overall several supports; the beam is subjected to alternate sagging also it becomes necessary to provide doubly reinforced section.	**01 mark each (any four)**	**04**

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
	B)	**Solve any ONE :**		**06**
	a)	**A R. C. beam 230x450mm effective is subjected to a working moment of 150 kN-m calculate area of steel I tension and compression zone. Use M 200 concrete and Fe415 steel. (Assume d' =45mm, and for d'/d=0.1, f_{sc} = 353 MPa)**		
	Ans.	Given data, b =230mm d = 450mm M =150 KN.m d'= 30mm f_{ck} =20 N/mm^2 f_y = 415 N/mm^2 f_{sc} = 353 N/mm^2 To find, A_{sc} = ? and A_{st} = ? M_u=1.5M =1.5x150= 225 KN.m		
		Step 1 **To find Xumax**, X_{umax} = 0.48d ……….. for fe 415 = 0.48 x 450 **X_{umax} = 216 mm**	**01**	
		Step 2 **To find M_{ulim} (M_{u1})** M_{ulim} = = 0.138 f_{ck} bd^2 ....for fe415 M_{ulim} = 0.138 x 20 x 230 x 450^2 **M_{ulim} = 128.547x10^6 N-mm**	**01**	
		Step 3 **find M_{u2}** M_{u2}= M_u – M_{ulim} M_{u2}= 225-128.54 **Mu_2 =96.46 KN.m**	**01**	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
4		**Step 4** **To find , A_{sc} and A_{st2}** **i)**$M_{u2} = A_{sc} (f_{sc} - f_{cc}) (d - d')$ $f_{sc} = 353$ N/mm^2 ……….given $f_{cc} = 0.45f_{ck} = 0.45 x 20 = 9$ N/mm^2 $96.46 \times 10^6 = A_{sc} (353 - 9) (450 - 45)$ $96.46 \times 10^6 = 139.32 \times 10^3 A_{sc}$		06
		A_{sc}= 692.36 mm^2	01	
		ii)$M_{u2} = 0.87 f_y A_{st2} (d-d')$ $96.46 \times 10^6 = 0.87 \times 415 \times A_{st2} (450 - 45)$ $96.46 \times 10^6 = 146.22 \times 10^3 A_{st2}$ $Ast_2 = 659.66$ mm^2 **Step 5**		
		$A_{sc}(f_{sc} - f_{sc}) = A_{st2} \times 0.87 f_y$ $692.36(353-9) = A_{st2} \times 0.87 \times 415$ $A_{st2} = 659.66 mm^2$ $A_{st1} = \frac{pt\lim \times b \times d}{100} = \frac{0.048 \times 20 \times 230 \times 450}{100}$ $A_{st1} = 993.6 mm^2$	01	
		$A_{st1} + A_{st2} = 659.66 + 993.6 = 1653.26 mm^2$	01	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
4	b) Ans.	**Fine the moment of resistance of a beam 230mm x 450mm deep reinforced with 4-16mm diameter bars in tension zone and 2-12mm diameter bars in compression zone. Assume effective cover of 40mm.** Given data :- b = 230 mm D = 450 mm d = D - d'= 450 - 40 = 410 mm d' = 40 mm A_{sc} = 2x (π/4)x12^2 = 226.19mm^2 A_{st} = 4x (π/4)x16^2= 804.24 mm^2 f_{ck} = 20 N/mm^2 f_y = 415 N/mm^2 Step 1 – To find Xu max X_{umax} = 0.48 d.........for Fe415 = 0.48 x 410 = 196.8 mm Step 2 - To find actual Xu , $Ast_2 = \frac{(Fsc - Fcc)Asc}{0.87fy}$ Fcc= 0.45fck = 0.45x20 = 9 N/mm^2 fsc is depend on d'/d ratio $\frac{d'}{d} = \frac{40}{410} = 0.0975$	 01 01	

d'/d	.05	0.10	0.15	0.20
fsc	355	352	342	329

$\frac{d'}{d}$	Fsc
0.5	355
0.0975	?
0.10	352

(Note : Given data is insufficient any suitable value of 'f_{sc}' assumed should be considered)

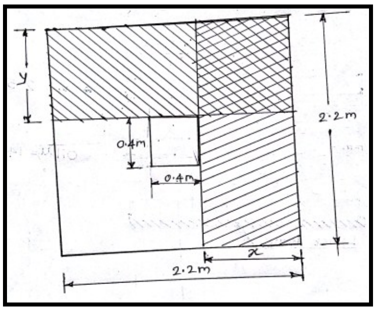
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
4		$Fsc = \left[\frac{(352-355)}{(0.1-0.05)} \times (0.9075-0.05)\right] + 355$		06
		fsc = 352.15 N/mm²	01	
		$Ast_2 = \frac{(352.15-9)x226.19}{0.87x415} = 214.97 \text{ mm}^2$		
		$Ast_1 = Ast - Ast_2$ $= 804.24-214.97$ $= 589.27 \text{ mm}^2$	01	
		Step 3 Find Xu		
		$X_u = \frac{0.87 \text{ fy } Ast_1}{0.36 \text{ fck b}}$ $X_u = \frac{0.87x415x589.27}{0.36x20x230}$ $X_u = 128.47 \, mm$	01	
		Xu < Xu max the section is Under reinforced		
		Step 4 Moment of Resistance		
		$M_u = 0.87 \times f_y \times A_{st} \times (d - 0.42X_u) + (f_{sc} - f_{cc}) \times A_{sc}(d - d')$ $M_u = 0.87 \times 415 \times 589.27 \times (410 - 0.42 \times 128.47) + (352.15 - 9) \times 226.19(410 - 40)$ $M_u = 104.468 \times 10^{-6} N - mm$ $M_u = 104.468 kN - m$	01	
5.	a)	**Attempt any TWO:**		16
		A doubly reinforced beam section 230mm x 40mm effective carries a factored moment of 175 kN-m. fine the area of steel. Required if M 20concrte and Fe 500 are used. Assume d'=50mm and σ_{sc}=353 N/mm².		
	Ans.	*Given :* $b = 230mm \quad d = 450mm \ (effective)$ $Md = 175kN - m$ $M20 \quad Fe500 \quad Fck = 20N/mm^2$ $fy = 500N/mm$ *Step* 1) To find x_{umax} $x_{u\max} = 0.46d$ $= 0.46 \times 450$ $= 207mm$	01	

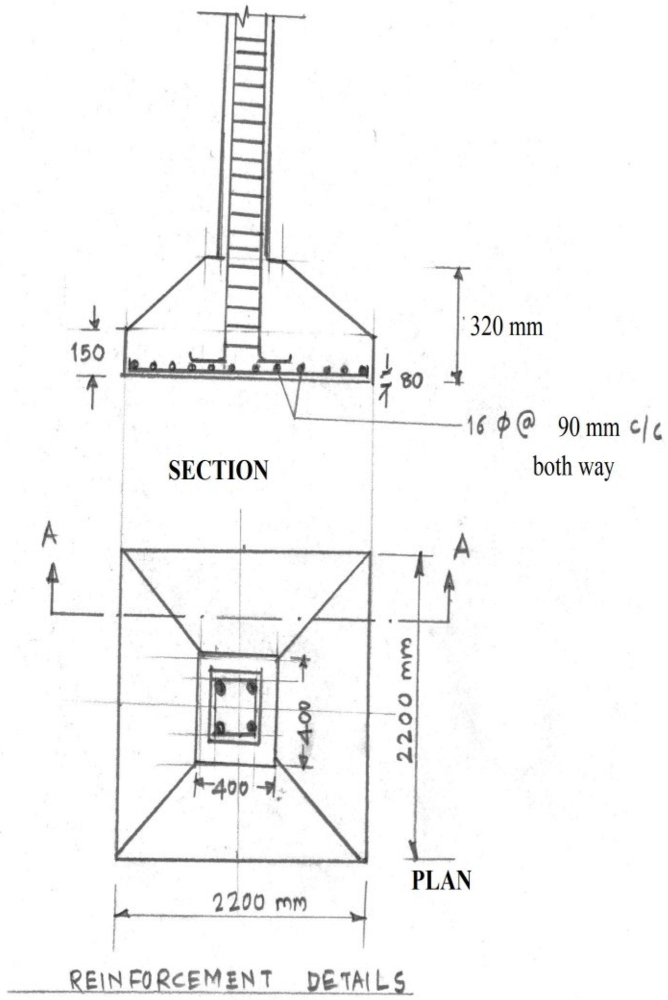
Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
5		*Step* 2) To find M_{ulim} $M_{u\lim} = 0.133 f_{ck} bd^2$ $= 0.133 \times 20 \times 230 \times 450^2$ $= 123.89 kN.m$	**01**	
		Step 3) To find A_{st_1} $Pt_{\lim} = 0.038 \times f_{ck} = 0.038 \times 20 = 0.76$ $A_{st_1} = \frac{Pt_{\lim} \times bd}{100}$ $= \frac{0.76 \times 230 \times 450}{100}$ $\boxed{A_{st_1} = 786.6 mm^2}$	**01**	
		Step 4) $Mu_2 = Md - Md_1$ $= 175 - 123.89$ $= 51.11 kN - m$	**01**	
		Step 5) To find Asc $Mu_2 = Asc(fsc - fcc)(d - d')$ $51.11 \times 10^6 = Asc(353 - 0.45 \times f_{ck}) \times (450 - 50)$ $51.11 \times 10^6 = Asc(353 - 0.45 \times 20) \times (450 - 50)$ $Asc = 371.44 mm^2$	**01**	
		Step 6) *To find* Ast_2 $Cu_2 = Tu_2$ $Asc(fsc - fcc) = Ast_2 \times 0.87 \times 500$	**01**	
		$371.44(353 - 0.45 \times 20) = Ast_2 \times 0.87 \times 500$ $Ast_2 = 293.74 mm^2$	**01**	
		total $Ast = Ast_1 + Ast_2$ $= 786.6 + 293.74$ $= 1080.34 mm^2$	**01**	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
5	**b)**	**A beam 250mm x 415 mm effective depth is reinforced with 4 bars of 16mm dia of grad Fe 415. The shear force of the support is 90 kN. Design the shear reinforcement. Use M 20 concrete and 6 mm dia. vertical stirrups of Fe 415 steel.**		
		%Pt. : **0.5**, **0.75**; **τ_c (MPa)** : **0.48**, **0.56**		
	Ans.	Given data: b=250mm $f_y=415 N/mm^2$ d=415mm $f_{ck}=20 N/mm^2$ 4 bars 16mm φ V=90kN $Ast=4\times\frac{\pi}{4}\times16^2=804.25mm^2$ Stirrups 6 mm φ		
		Step 1) To calculate factored shear force $Vu=V\times1.5$ $=90\times1.5$ $=135kN$	**01**	
		Step 2) To calculate shear stress(τ_v) $\tau_v=\frac{Vu}{bd}=\frac{135\times10^3}{230\times415}=1.3N/mm^2$ $\tau_{cmax}=2.8N/mm^2$ ....for M_{20} concrete	**01**	
		Step 3) Calculate pt%, Ast, τ_c $pt=\frac{Ast}{bd}\times100=\frac{804.25}{250\times415}\times100=0.78$ $pt=0.78$ pt τ_c 0.75 0.56 1.0 0.62	**01**	
		(Note: Given data is insufficient. Any suitable value of τ_c assumed should be considered)		

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
5		$pt_1 = 0.75 \quad \tau_{c1} = 0.56$ $pt_2 = 1.0 \quad \tau_{c2} = 0.62$ $pt = 0.78 \quad then \quad \tau_c$ $\tau_c = \tau_{c1} + \frac{(\tau_{c2} - \tau_{c1})}{(pt_2 - pt_1)} \times (pt - pt_1)$ $\tau_c = 0.56 + \frac{(0.62 - 0.56)}{(1.0 - 0.75)} \times (0.78 - 0.75)$ $\tau_c = 0.57 N/mm^2$ $\tau_v = 1.3 N/mm^2 > \tau_c = 0.57 N/mm^2$ Shear reinforcement is required	01	08
		Step 4) Shear force for which shear reinforcement is required $Vus = Vu - \tau_c bd$ $= 135 \times 10^3 - 0.57 \times 230 \times 415$ $= 80.593 kN$ $= 80593 N$	01 01	
		As bent up bars are not provided $Vusv = Vus = 80593N$ Provide 6mm ϕ two legged vertical stirrups		
		Step 5) $Spacing(Sv) = \frac{0.87 f_y Asv.d}{Vusv}$ $Sv = \frac{0.87 \times 415 \times 2 \times \frac{\pi}{4} \times 6^2 \times 415}{80593}$ $Sv = 105.13 \approx 100mm$ c/c	01	
		$Sv_{min} = \frac{0.87 f_y Asv}{0.4b} = \frac{0.87 \times 415 \times 2 \times \frac{\pi}{4} \times 6^2}{0.4 \times 230}$ $Sv_{min} = 221.92 \approx 220mm$ $Sv_{max} = 0.75d \quad or \quad 300$ $Sv_{max} = 0.75 \times 415 \quad or \quad 300$ $Sv_{max} = 311.25 \; or \quad 300$ Provide 6mmϕ two legged vertical stirrups @ 100mmc/c.	01	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
5	c)	**Design on R.C. column footing with following data.** **Size of column = 400mm x 400mm** **Safe bearing capacity = 1200 kN/m²** **Concrete M20 and steel Fe 415 is used.** **Calculate depth of footing from B.M criteria.** **No shear check is required.**		
	Ans.	**Given-** Size of column – 400mm X 400 mm Safe bearing capacity of soil = 200 kN/m² Load on column is 1200 kN f_{ck}= 20 N/mm² fy= 415 N/mm² **Step 1 :** Ultimate S.B.C (q_u)= 2 X 200= 400 kN/m² **Step 2 :** Size of footing- $W_U = W \times \gamma_f = 1200 \times 1.5 = 1800$ kN $A_f = 1.05 \times W_U / q_u$ $= 1.05 \times 1800/400$ $=4.725$ m² L=B= $\sqrt{AF} = \sqrt{4.725}$ = 2.173m = say 2.20m Adopt footing of size 2.20m X 2.20m **Step 3 :** Upward soil pressure p = W_u/(L X B) = 1800/(2.2 X 2.2) = 371.90 KN/m²	01 01 01 01	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
5		**Step 4 :** Depth for flexure  Let $X_1 = Y_1 =$ projection beyond column $= (2.2-0.4) / 2 = 0.9$ $M_x = M_y = 1 \times X_1 \times p \times (X_1/2)$ $M_x = M_y = 1 X 0.9 X 371 X(0.9/2)$ $= 150.62$ KNm $d_{reqd} = \sqrt{Mx / q.fck.b}$ $d_{reqd} = \sqrt{(150.62 \times 10^6 / 0.138 \times 20 \times 1000)}$ = 233.61 mm say 240 mm. Adopt cover of 80 mm D= 240+80= 320 mm **Step 5 :** $Ast = \frac{0.5 f_{ck}}{f_y}\left[1-\sqrt{1-\frac{4.6 \times M_u}{f_{ck} bd^2}}\right] bd$ $Ast = \frac{0.5 \times 20}{415}\left[1-\sqrt{1-\frac{4.6 \times 150.62 \times 10^6}{20 \times 1000 \times 240^2}}\right] 1000 \times 240$ $Ast = 2132.120 mm^2$ Using 16 mm diameter Spacing, $S_x = S_y = 1000$ x Aø/ Ast $= 1000 X (\pi/4) X 16^2 / 2132.120$ = 94.30 mm say 90 mm c/c Provide 16 mm ø @ 90 mm c/c both way	01 01 01	08

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
5		**Step 6 :** Development length- $L_d = (0.87\ f_y \times ø) / (4\ \tau_{bd})$ $= (0.87 \times 415 \times 16) / (4 \times 1.2 \times 1.6)$ $= 752.187$ mm say 760 mm This length is available from face of column. Provide 350mm depth near the face of column and reduce depth of footing 150mm at the edge. 	01	

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
6.		**Attempt any FOUR :**		**16**
	a)	**Differentiate under reinforced and over reinforced section with reference to area of steel. Depth of NA moment of resistance.**		
	Ans.	(see table below)	**04**	**04**
	b)	**Write IS specification of minimum eccentricity and transverse reinforcement for an axially loaded column.**		
	Ans.	IS specification for e_{min}. & transverse steel **Minimum eccentricity: -** e_{min}.= Lo/500 + D/30 Or **20 mm** whichever is greeter Lo= unsupported Length D=lateral dimension	**02**	**04**
		Transverse reinforcement: - **I) Pitch -** The spacing of the link should not exceed the least of the following. 1. The least lateral dimension of column. 2. Sixteen times the diameter of the smallest longitudinal bar. 3. 300mm	**01**	

	Under reinforced section	**Over reinforced Section**
Area Of Steel	Less compared to over reinforced section. Ast < Ast max.	More compared to under reinforced section. Ast > Ast max.
Neutral Axis	Xu < Xumax	Xu > Xumax
Moment of resistance	Mu = Tu.z =0.87 fy Ast(d-0.42xu)	Mu = Cu.z =0.36 fck b xu(d-0.42xu)

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
6		**II) Diameter of link** 1. The diameter of the link should be at least one fourth of the longitudinal steel. 2. In any case the links should not be less than 6mm in diameter. 3. Largest diameter of condition 1 and 2.	01	
	c) Ans.	**What is minimum and maximum percentage of tension steel that should be provided in flanged beam as per IS specification.** **As per IS 456:2000 Clause No. 26.5.1.1** Min. % of Tension Steel: It shall be not less than - $A_s/bd = 0.85 / fy$; Hence, $A_s = (0.85 \times b \times d) / fy$ Max. % of Tension Steel: It shall not exceed (0.04bD) Where, b = Breadth of web of Flanged beam d = Effective Depth	04	04
	d) Ans.	**Find limiting moment of resistance (Mu) of a T beam with following data, bf= 1500 mm, bw =230mm, Asf=2200 mm^2, concrete M 20 & Fe 415 steel.** *Given –* $bf = 1500mm$ $bw = 230mm$ $d = 730mm$ $Df = 120mm$ $Asf = 2200mm^2$ $M20$ *and* $Fe415$ *Step* 1) *To* find Xumax Xumax = 0.48d $= 0.48 \times 730$ $= 350.4mm$ Consider Ast=Asf $Xu = \frac{0.87\ fy\ Ast}{0.36\ fck\ bf} = \frac{0.87 X 415 X 2200}{0.36 X 20 X 1500}$ $Xu = 73.54mm$ $Xu < Df$ Neutral axis within the flange.	01 01 01	04

Que. No.	Sub. Que.	Model Answers	Marks	Total Marks
6		Mu= $0.87f_y \cdot A_{st}\left(d-0.42X_u\right)$		
		Mu= $0.87\times415\times2200\times\left(730-0.42\times73.54\right)$		
		Mu $=555.313\times10^6 N-mm$	**01**	
		Mu $=555.313kN-m$		
	e)	**Calculate the area of longitudinal, steel for short circular column of dia. 300mm with eff. Length 5.0m to carry a factored load of 1000kN. Use M20 concrete & Fe 500 steel.**		
	Ans.	*Given* :		
		$D=300mm$		
		$L_{eff}=5.0m=5000mm \quad Pu=1000kN.$		
		M20 And Fe-500		
		For circular column		
		Ag= $\frac{\pi}{4}\times D^2$	**01**	
		Ag $=\frac{\pi}{4}\times300^2$		
		Ag $=70.69\times10^3 mm^2$		
		$Ag=Asc+Ac$	**01**	
		$Ac=Ag-Asc$	**01**	
		$Ac=(70.69\times10^3-Asc)$		
		$Pu=0.45fckAc+0.67fyAsc$		**04**
		$1000\times10^3=0.45\times20\times(70.69\times10^3-Asc)+0.67\times500\times Asc$	**01**	
		$Asc=1115.92mm^2$		