MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION
(Autonomous)
(ISO/IEC - 27001 - 2013 Certified)

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WINTER–19 EXAMINATION

MODEL ANSWER

Subject Name: DESIGN OF RCC STRUCTURES **Subject 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 etc 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 candidate and 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 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.

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<tr><th>Q. No.</th><th>Sub Q. N.</th><th>Answers</th><th>Marking Scheme</th><th>Total Marks</th></tr>
<tr><td>1</td><td>a)</td><td>Solve any THREE:</td><td></td><td>12</td></tr>
<tr><td></td><td>(a) i)</td><td>Define 'partial safety factor' and state it's value for steel and concrete.
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.</td><td>1</td><td></td></tr>
<tr><td></td><td></td><td>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.</td><td>1</td><td></td></tr>
<tr><td></td><td></td><td>Partial safety factors for steel and concrete
<table>
<tr><th rowspan="2">Limit state</th><th colspan="2">Material</th></tr>
<tr><th>Concrete</th><th>steel</th></tr>
<tr><td>Ultimate serviceability</td><td>1.5</td><td>1.15</td></tr>
<tr><td>Deflection</td><td>1.0</td><td>1.0</td></tr>
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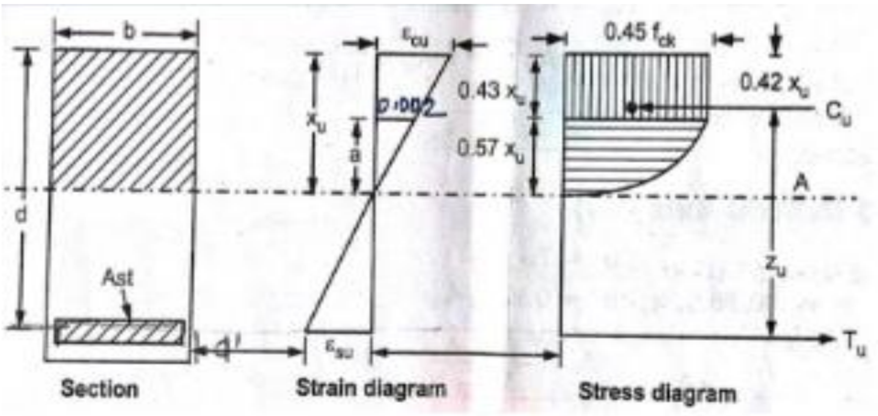
	(a) ii) **Ans**	**Write any four assumption is design for limit state of collapse in flexure**. i) Plane section normal to the axis remains plane after bending. ii) The maximum strain in concrete at the outermost compression fiber is taken as 0.0035 in bending. iii) For design purpose, the compressive strength of concrete in structure shall be assumed to be 0.67 times the characteristic strength. The partial safety factor ϒm= 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 ϒm of steel reinforcement, equal to 1.15 shall be applied. vii) The maximum strain in the tension reinforcement in the section at failure shall not be less than fy/(1.15 Es) + 0.002.	**1 M each for any four**	
Q.1	**(a) iii)** **Ans**	**State any four ductile detailing provision as per IS 13920.** **Requirements of ductility for RCC members.** 1. The factored axial stress on the member under earthquake loading shall not exceed 0.1 fck. 2. The member shall preferably have a width-to-depth ratio of more than 0.3. 3. The width of the member shall not be less than 200 mm. 4. The depth D of the member shall preferably be not more than l/4 of the clear span. 5. If the average axial stress P/A on the column under earthquake conditions is less than 0.1 fck , the column reinforcement shall be designed according to the requirements of flexure members. . But if P/A greater or equal to 0.1 fck, special confining reinforcement will be required at the column ends. 6. The minimum dimension of the member shall not be less than 200 mm. 7. The ratio of the shortest cross-sectional dimension to the perpendicular dimension shall preferably not be less than 0.4. **Note: Student can write any four provisions from IS 13920 for flexural and columns . Marks to be given to the student if any other provision from IS 13920 is written.**	**1 M each for any four**	
Q.1	**(a)iv)** **Ans**	**State advantages (any two) & disadvantages (any two) of pre-stressed concrete.** **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. 7. Factory products are possible. 8. Prestressed members are tested before use.	**1 M each for any 2**	

		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 M each for any 2**	
Q.1	**(a)v)** **Ans**	**State the values for maximum spacing of bars in slabs & minimum shear reinforcement for beams.** **Maximum spacing of bars in slabs** Main steel – 3d or 300 mm whichever is smaller Distribution steel – 5d or 450 mm whichever is smaller Where d is the effective depth of slab Minimum shear reinforcement for beams in the form of stirrups shall be provided such that $\frac{Asv}{bsv} > \frac{0.4}{0.87\ fy}$ Asv = total cross sectional area of stirrup leg effective in shear. b = Breadth of the beam fy = characteristics strength of stirrup reinforcement in N / mm^2 which shall not be greater than 415 N / mm^2	**1** **1** **1** **1**	
Q.1	**b)** **(b) i)** **Ans**	**Attempt any ONE** **An RCC beam 230 mm wide & 400 mm deep effective is supported over an effective span of 5.5 m. It is reinforced with 4-20 mm dia. bar along tension side only. Calculate the ultimate moment of resistance & working load if M 20 concrete & Fe 415 steel is used.** B = 230 mm D = 400 mm Le = 5.5m Ast = $\frac{4 \times \pi \times 20^2}{4}$ = 1256 mm^2 MR =? w =? fck = 20 N/mm^2 fy = 415 N/mm^2 **Depth of Neutral axis** xu $= \frac{0.87\ fy\ Ast}{0.36\ fck.b}$ xu = $\frac{0.87 \times 415 \times 1256}{0.36 \times 20 \times 230} = 273.84\ mm$ **Limit value of Neutral axis** xu max = 0.48 d	**1**	**6**

		= 0.48 x 400 = 192 mm As xu > xu max the section is over reinforced **Moment of resistance** MR = 0.138 fck bd^2 = 0.138 x 20 x 230 x 400^2 = 101.57 x10^6 Nmm = 101.57 kNm Or MR = 0.36 fck . b xu max (d – 0.42 xu max) = 0.36 x 20 x 230 x 192 (400 – 0.42 x 192) = 101.54 x 10^6 Nmm = 101.54 kNm Equating MR to BM M = $\frac{wd\ le^2}{8}$ wd (factored load) = $\frac{8\ x\ 101.57}{5.5^2}$ = 26.86 kN/m Working load = $\frac{\text{Factored load}}{\text{Partial Safty factor}}$ Working load w = $\frac{26.86}{1.5}$ **= 17.91 kN/m**	**1** **1** **1** **1** **1**	
Q. 1	**(b) ii)** **Ans**	**Draw stress - strain diagram for singly reinforced beam in LSM. State the values of position of N.A., moment of resistance & percentage steel for balanced section. For all grades of steel i.e. Fe 250, Fe 415 & Fe 500**  	**3 M**	

Grade of steel	Xu max	Mu lim	Pt lim
Fe 250	0.43d	0.149 fck bd^2	0.88 fck
Fe 415	0.48d	0.138 fck bd^2	0.048 fck
Fe 500	0.46d	0.133 fck bd^2	0.038 fck

3M

Where xu max is the value of position of neutral axis for balanced section

Mu lim is the value of moment of resistance for balanced section

Pt lim is the percentage steel for balanced section

Q 2 **Attempt any TWO:** **16**

a) **Design a slab for a hall 9 x 3.5 m for following data - live load = 2 kN/m2, floor finish = 1 kN/m^2, width of support = 230 mm, M.F. = 1.5. Use M15 concrete & mild steel. Draw sketch of reinforcement details. Check for shear & development length need not to be taken.**

Ans

Ly/lx = 9/3.5 = 2.57>2 :- one way slab

LL = 2kN/m^2

FF = 1kN/m^2

Width of support = 230mm

MF = 1.5

fck =15N/mm^2

fy = 250N/ mm^2

Xumax = 0.53d

Depth from deflection criteria:

D = span/20 x MF

=3500/20 x 1.5 = 116.67mm

Overall depth D = d + clear cover + Ø/2

= 116.67.67 + 20 + 10/2 (Assuming 100 bar)

= 141.67mm

=150mm

davailable = 150 – 20 – 10/2 1

= 125mm

Effective span

Le = l + t or l + d whichever is smaller

=3500 + 230 or 3500 + 125

= 3730mm or 3625mm 1

le = 3.625

Load calculation

Self weight of slab = 0.15 x 25 = 3.75kN/m^2

= 2KN/m^2

= 1KN/m^2 / Total Load = 6.75kn/m^2 1

Factored Load wd = 6.75 x 1.5

= 10.125KN/m^2

Factored max bending moment

Md = wd x le/8

$$\frac{10.125\, x\, 3.625^2}{8} = 16.63KNm$$

Required effective depth for fy 250,

$$M = 0.149\, fck\, bd^2$$

0.149 x 15 1000 x d^2 = 16.63 x 10^6

d=86.26mm < d provided 1

D = 150mm

d = 125mm

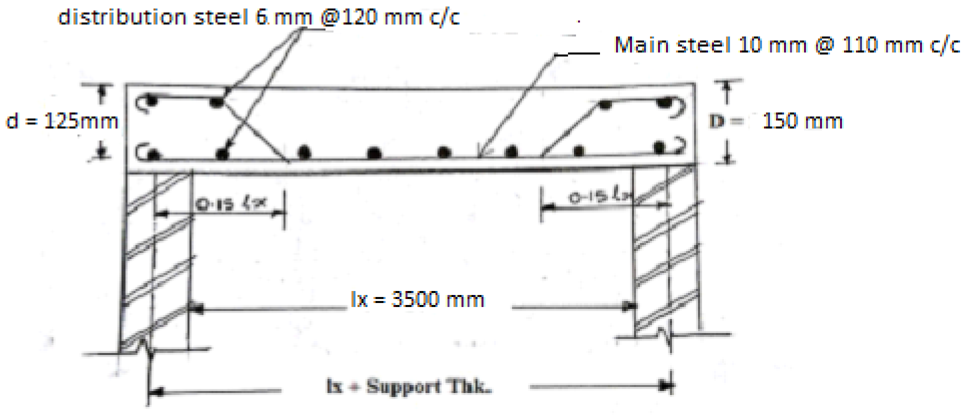
Area of main steel

Ast = 0.5 x fck x b x d {1 – SQRT[1 – (4.6 x Mu) / (fck x b x d2)]} / fy
= 0.5 x 15 x1000 x 125 {1 – SQRT[1 – (4.6 x 16.63x 10^6) / (15 x 1000 x 125^2)]} / 250
= 672.24mm^2

Spacing of main reinforcement using 10mm bars 1

S = AØ/Ast x b = ∏x10^2/4 x1000/ 672.24
= 116.77mm = 110mm
Max Spacing = 3d or 300mm or 110 whichever is less
=3 x 125 or 300mm or 110
As S<max, provide 10mm bars or 110mm c/c 1
Area and spacing of distribution steel
Astd = 0.15/100 x b x D
= 0.15/ 100 X 1000 X 150
= 225mm^2
Spacing of 6mm ØMS distribution bars (AØ= 28.26mm^2)
Sd = AØ/Astd x b
= 28.26/225 x 1000
= 125.6mm = 120mm c/c
Max spacing Sd max = 5d or 450mm
= 5 x 125 or 450mm
= 625 or = 450mm
Sd < Sdmax

:- providing 6mm Ø distribution bars α 120mm c/c 1



Reinforcement details of one way slab

1

b) **Design a slab for a hall size of 4 m x 5.5 musing M 20 concrete & Fe 415 steel. Take live load = 2 kN/m^2 floor finish = 0.5 kN/m2, MF = 1.4, Lx = 0.114, xy = 0.035, check for shear & deflection need not to be taken. Draw reinforcement sketch.**

Ans

ly = 5.5m
lx = 4m
fck = 20N/mm^2
fy = 415N/mm^2
LL = 2KN/mm^2
FF = 0.5KN/m^2
Mf = 1.4

$$\frac{ly}{lx} = \frac{5.5}{4} = 1.38 < 2 \quad Two\ way\ slab$$

$$d = \frac{span}{20\ x\ MF}$$

$$= \frac{4000}{20\ x\ 1.4} = 142.86mm$$

1

Overall depth = D = 142.86 + cover + Ø/2

= 142.86 + 20 + 10/2 [Assuming 10mm bar]
=167.86mm
=170mm
dvail = 170 – 20 – 10/2
= 142mm

Effective span:

lex = l + d
= 4000 + 145
= 4145mm
= 4.145m

1

Loads

Self weight of slab = 0.17 x 25 = 4.25kN/m^2
= 0.5kN/m^2

= 2kN/m^2 = 6.75kN/m^2

Factored load wd = 6.75 x 1.5

= 10.13kN/m

Factored Bending Moment

Mux = ɑx x wu x lex^2

= 0.114 x 10.13 x 4.145^2

= 19.84 kNm

Muy = ɑy x wu x lex^2

= 0.035 x 10.13 x 4.145^2

1

= 6.09 KNm

Effective depth of slab

0.138 fck bd^2 = Md

0.138 x 20 x 1000 d^2 = 19.84 10^6

d = 84.78mm < 145 mm :- OK

D= 170mm

d = 145mm

Area and spacing of steel

Astx = $0.5\frac{fck}{fy}\sqrt{1-1\frac{4.6Md}{fckbd^2}}]bd$

1

$= \frac{0.5 \quad 20}{415} x^{[1-}\sqrt{1-\frac{4.6\ x\ 19.84\ x\ 10^6}{20\ x\ 1000\ x\ 145^2}}]\ x\ 1000\ x\ 145 = 402.32mm^2$

$\text{Astmin} = \frac{0.12}{100}\, x\ bd$

$= \frac{0.12}{100}\, x\ 1000\ x\ 170 = 204mm^2$

$Astx > Astmin : -OK$

$area\ of\ 10mm\ bars\ (AØ = \prod x\frac{10^2}{4} = 78.5mm^2$

$\text{Sx} = \frac{78.5\ x\ 1000/758.32}{402.32} = 195.15mm$ = 190mm

1

Spaing =$\frac{A\phi x1000}{Ast}$

Note : students can also calculate using 8mm bars

Smax = 3d ɑ 300 whichever is min

= 3 x 145

= 435_{mh} ɑ 300mm

S x < Smax

Provide 10mm bar ɑ 170mm c/c

Asty = $0.5\frac{fck}{fy}\sqrt{1-1\frac{4.6Md}{fckbd^2}}]bd$

1

= 0.5 x 20/415$^{[1-}$$\sqrt{1-\frac{4.6\ x\ 6.09\ x\ 10^6}{20\ x\ 1000\ x\ 145^2}}]\ x\ 1000\ x\ 145 = 118.39mm^2$

Asty < Astmin

Asty = 204mm$_2$

OR

d = 145-10 = 135mm

Asty = = 0.5 x

$20/415^{[1-}\sqrt{1-\frac{4.6\,x\,6.09\,x\,10^{6}}{20\,x\,1000\,x\,135^{2}}}]\,x\,1000\,x\,145 = 127.51mm^{2} < Astmin$

Asty = 204mm2

Spacing using 8mm bars area of 8mm bar is $\frac{\pi}{4}$ x $8^{2} = 50.26\,mm^{2}$

$$Sy = \frac{50.26\,x\,1000}{204}$$

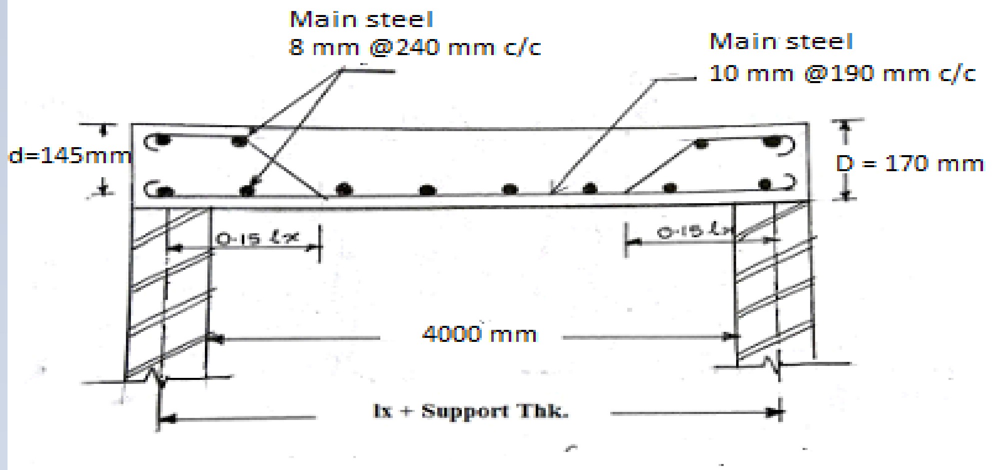
= 246.37 mm = 240mm c/c

1

Smax = 3d or 300 whichever is less

= 435mm or 240mm c/c

Provide 8mm @ 240mm c/c



Reinforcement details of two way slab

1

c)

Design a cantilever chajja for a span of 2 m carrying LL = 2.5 kN/m² & FF = 0.5 kN/m2. Use M20 concrete & Fe 415 steel. Take MF = 1.6. Check for shear & deflection & development length need not to be taken. Draw reinforcement detail sketch.

Define over reinforced sections and state two reasons due to which they are avoided.

Ans

Lx = 5.5m

LL = 2.5KN/mm^{2}

FF = 0.5KN/m^{2}

fck = 20N/mm^{2}

fy = 415N/mm^{2}

Mf = 1.6

Xx =- 0.114, xy = 0.035

$$\frac{ly}{lx} = \frac{5.5}{4} = 1.38 < 2 Two\ way\ slab$$

$$d = \frac{span}{7\,x\,MF}$$

$$= \frac{2000}{7\,x\,1.6} = 178.57mm$$

Assuming 10mm bars and 20mm cover

$$D + dc + \frac{Ø}{2}$$

$$= 178.57 + 20 + \frac{10}{2}$$

$$= 203.57mm$$

1

= 210mm

Note : Student can assume any overall depth grater then 203.57mm

$$davail = 210 - 20 - \frac{10}{2}$$

= 185mm

Effective span

$$le = l + \frac{d}{2}$$

$$2000 = + \frac{185}{2} = 2092.5 = 2.093m$$

1

Load calculations

Self weight of slab = 0.21 x 25 = 5.25KN/m^2

Live load = 2.5KN/m^2

=Floor finish = 0.5KN/m^2

Total w = 8.25KN/m^2

Factored wd = 8.25 x 1.5 = 12.38KN/m^2

Factored max Bm

$$Md = \frac{wd \text{ x } le^2}{2}$$

$$= \frac{12.38 \text{ x } 2.093^2}{2} =$$

1

= 27.12 kNm

Required effective depth

Md = 0.138 fck bd^2

0.138 x 20 x 1000 x d^2= 27.12 x 10^6

d = 99.13 mm < d available : ok

: D = 210 mm

d = 185 mm

1

Area and spacing of main steel

$$Ast = \frac{0.5\,fck}{fy}\left[1 - \frac{\sqrt{1-4.6md}}{fck\,bd^2}\right]bd$$

$$= \frac{0.5 \text{ x } 20}{415}\left[1 - \frac{\sqrt{1-4.6 \text{ x } 27.12 \text{ x } 10^6}}{20 \text{ x } 1000 \text{ x } 185^2}\right]1000 \text{ x } 185$$

= 426.64 mm^2

$$Astmin = 0.12x\frac{bd}{100}$$

$$= \frac{0.12}{100} \text{ x } 1000 \text{ x } 210 = 252mm^2$$

1

Ast > Astmin : OK

Spacing using 8mm bars (AØ= 50.26mm^2

$$sx = 1000 \text{ x} \frac{AØ}{Ast}$$

$$= 1000 \text{ x} \frac{50.26}{426.64} = 117.80mm = 110mm$$

Smax 3d or 300mm whichever is less = 3 x 185 = 555mm or 300mm

1

Sx < Smax provide 8mm or 110mm c/c

Area and spacing of distribution steel.

$$Astd = \frac{0.12}{100} \text{ x } b \text{ x } D$$

$$= \frac{0.12}{100} \text{ x } 1000 \text{ x } 210 = 252mm^2$$

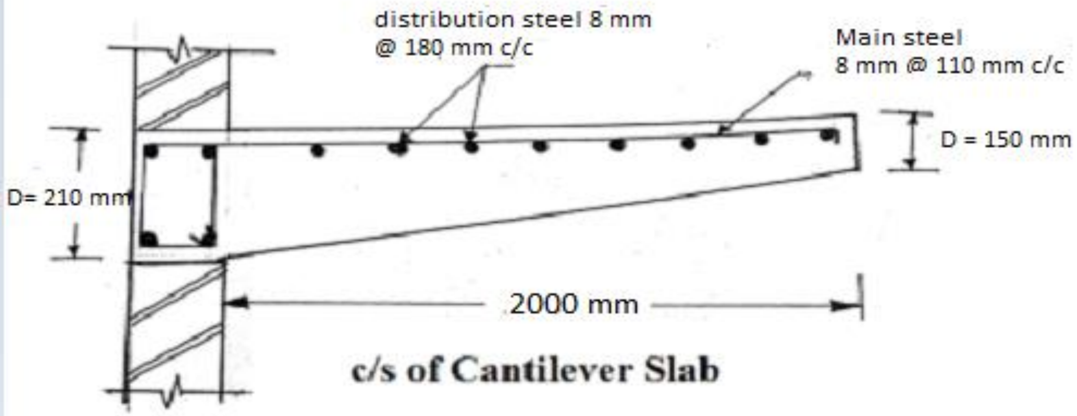
Spacing using 8mm bars

$$sd = 1000\ x \frac{A\text{Ø}}{Astd}$$

$$= 1000\ \text{x} \frac{50.26}{252} = 199.44mm = 180mm$$

1

Smax = 5d or 450mm whichever is less
= 5 x 185 or 450mm
= 935 or 450mm
Sd < Smax : OK
provide 8 mm or 180 mm c/c



c/s of Cantilever Slab

1

Q. 3 ## Attempt any FOUR: **12**

a) **State the IS specifications for effective flange width of T & L beam with meaning of terms used in it.**

Ans

(a) For T-beams, bf = $\frac{lo}{6} + bw + 6Df$

(b) For L-beam, bf = $\frac{lo}{12} + bw + 3Df$

(c) For isolated/individual beams, the effective flange width may be obtained as below but in no case greater than the actual width 'b'.

2 M Each beam

i) bf = $\frac{lo}{\left(\frac{lo}{b}\right)+4} + bw\ for\ T - beams.$

ii) bf = $\frac{0.5lo}{\left(\frac{lo}{b}\right)+4} + bw\ \text{bw for L} - \text{beams}$

where, bf = Effective flange width.
l_0 = Effective span.
bw = Breadth of web.
Df = Thickness of flange, and
b = Actual width of flange.

	b)	**Calculate effective flange width for a T beam having c/c distance between supports = 8.4, c/c distance between beam = 4m, slab thickness = 150 mm, width of rib = 350 mm, support thickness = 400 mm**		
		For the beams		
		c/c distance between beams = 4.15 m		
		c/c distance between support = 8.4 m		
		slab thickness = 150mm		
		width of rib = 350mm	**2**	
		support thickness = 400 mm		
		effective width of concrete		
		$bf = \frac{lo}{6} + bw + 6Df$		
		$bf = \frac{8400}{6} + 350 + 6x150$		
		= 2650 mm	**2**	
	c)	**Find development length of 16 mm dia. bar in tension & compression. Use M20 concrete & Fe 500 grade steel. Take τbd = 1.2 N/mm2**		
	Ans	$fck = 20\ N/\ mm^2$		
		d = 16 mm		
		$fy= 500\ N/mm^2$		
		$\tau bd= 1.2N/mm^2$		
		for deformed bars		
		$\tau bd = 1.2 \text{ x } 1.6 = 1.92\ N/mm^2$		
		In tension		
		Development length Ld = $\frac{0.87\ fy\ Ø}{4\tau bd}$	**1**	
		$= \frac{0.87 \text{ x } 500 \text{ x } 16}{4\ x\ 1.92}$		
		= 906.25 mm	**1**	
		In compression		
		$\tau bd = 1.25\ (1.2 \text{ x } 1.6) =2.4\ N/mm^2$	**1**	
		Development length Ld = $\frac{0.87\ fy\ Ø}{4\ \tau bd}$		
		$= \frac{0.87 \text{ x } 500 \text{ x } 16}{4\ \text{ x } 2.4}$		
		= 725 mm	**1**	
	d)	**State any four uses of bent up bar in shear reinforcement.**		
		Use of bent up bars in shear reinforcement		
		1) Bent up bars are provided to complement the vertical stirrups in resealing shear.		
	Ans	2) Bent up bars are good in restraining crack width which may be developed due to diagonal tension	**1 M each**	
		3) No additional steel is required, because only the unwanted tension bars are used by bending these bars, hence in provides economy.		
		4) Half of the total shear reinforcement can be contributed by bent up bars.		

Q. 4	**(a)**	**Attempt any THREE:**		**12**
	a) i)	**State any four types of losses in pre-stressed concrete with their percentage.**		
	Ans.	**Losses in pre-stressing:** (i) Due to elastic shortening of concrete – 1% (ii) Due to creep of concrete - 5% (iii) Due to shrinkage of concrete - 6% (iv) Due to creep in steel - 3% (v) Due to frictional loss (vi) Due to slip at anchorages	**1 Mark each any four**	
	a) ii)	**State any four functions of reinforcement.**		
	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. 2. In case of columns the steel is provided to resist the direct compressive stress as well as bending stresses if any. 3. In case of beams stirrups are provided to resist the diagonal tension due to shear and hold the main steel in position. 4. The box type mesh of reinforcement is provided to resist torsion. 5. The steel is provided in the form of rectangular, circular, lateral ties or spirals to prevent bucking of main bars in column. 6. The distribution steel is provided to distribute the concentrated loads and to reduce the effects of temperature and shrinkage and to hold main bars in position.	**1 Mark each any four**	
	a) iii)	**State any four conditions where doubly reinforced beam is provided.**		
	Ans.	1. When the applied moment exceeds the moment resisting capacity of a singly reinforced beam. 2. When the dimension b and d of the section are restricted due to architectural, structural or constructional purposes. 3. When the sections are subjected to reversal of bending moment. e. g. piles, underground water tank etc. 4. In continuous T-beam where the portion of beam over middle support has to be designed as doubly reinforced. 5. When the beams are subjected to eccentric loading, shocks or impact loads.	**1 Mark each (any four)**	

a) iv) **Calculate working load carrying capacity of column 300 x 300mm provided with 4 - 20 mm Ø bars. M20 concrete & Fe415 steel is used.**

Ans. Given data :

Size of column = 300 x 300mm

4 – 20 mm Ø bars

M20 $\Longrightarrow$ $f_{ck} = 20 \text{ N/mm}^2$

Fe415 $\Longrightarrow$ $f_y = 415 \text{ N/mm}^2$

To find, working load carrying capacity of column = P =?

Step 1: Gross area = $A_g = 300 \times 300$

$$\mathbf{A_g = 90000 \text{ mm}^2}$$

Step 2: Area of steel, $A_{sc} = 4 \times \frac{\pi}{4} \times d^2$

$$= 4 \times \frac{\pi}{4} \times (20)^2$$

$$A_{sc} = 1256.64 \text{ mm}^2$$

1M

Step 3: Area of concrete, $A_c = A_g - A_{sc}$

$$= 90000 - 1256.64$$

$$\mathbf{A_c = 88743.36 \text{ mm}^2}$$

1M

Step 4: Ultimate load carrying capacity, P_u:

$$P_u = 0.4 * f_{ck} * A_c + 0.67 * f_y * A_{sc}$$

$$P_u = [0.4 * 20 * 88743.36] + [0.67 * 415 * 1256.64]$$

$P_u = 1059355.63$ N

$\mathbf{P_u = 1059.35}$ **kN** 1M

(Working load carrying capacity) $P = \frac{P_u}{\Upsilon_f}$

$$P = \frac{1059.35}{1.5}$$

P = 706.233 kN 1M

Q. 4 **b) i)** **Attempt any ONE:** **6**

Find ultimate moment of resistance of a beam 230 x 460 mm deep to the Centre of tension reinforcement. It is provided with 2-16 mm Ø bars at top & 4 – 20 mm Ø bars at bottom. Take effective cover on both side = 40 mm, f_{sc} = 217 N/mm^2. Use M15 concrete & M. S. Grade – I steel. Neglect f_{cc}.

Ans.

Given data :

b = 230 mm

d = 460 mm

d’ = 40 mm

f_{sc} = 217 N/mm^2

2 – 16 mm Ø bars at top

A_{sc} = 2 x $\frac{\pi}{4}$ x d^2

= 2 x $\frac{\pi}{4}$ x (16)^2

A_{sc} = 402.12 mm^2

4 – 20 mm Ø bars at bottom

A_{st} = 4 x $\frac{\pi}{4}$ x d^2

= 4 x $\frac{\pi}{4}$ x (20)^2

A_{st} = 1256.64 mm^2 **1M**

M15 $\Longrightarrow$ f_{ck} = 15 N/mm^2

M. S. Grade, F_e250 $\Longrightarrow$ f_y= 250 N/mm^2

To find ultimate moment of resistance = M_u = ?

Step 1: To find X_{umax}

X_{umax} = 0.53d = 0.53 x 460

X_{umax} = 230 mm

Step 2: To find actual X_u: **1M**

$$A_{st2} = \frac{(f_{sc} - f_{cc}) * A_{sc}}{0.87 * f_y}$$

$$A_{st2} = \frac{(217 - 0) * 402.123}{0.87 * 250}$$

A_{st2} = 401.20 mm^2

$A_{st1} = A_{st} - A_{st2}$ = 1256.64 – 401.20

A_{st1} = 855.44 mm^2 1M

$$x_u = \frac{0.87 * f_y * A_{st1}}{0.36 * f_{ck} * b}$$

$$x_u = \frac{0.87 * 250 * 855.44}{0.36 * 15 * 230}$$ 1M

X_u = 149.80 mm < X_{umax} = 230 mm . . . . Section is under reinforced

<u>Step 3:</u> To find Ultimate moment of resistance M_u:

$$M_u = [0.87 * f_y * A_{st1} * (d - 0.42 * x_u)] + [(f_{sc} - f_{cc}) * A_{sc} * (d - d')]$$

M_u = 0.87 x 250 x 855.44 x (460 – 0.42 x 149.80) + (217 −0)x 402.12 x (460 – 40) 1M

M_u = 0.87 x 250 x 855.44 x (460 – 0.42 x 149.80) + (217 – 0) x 402.12 x (460 – 40)

M_u = 119.65 x 10^6 N-mm.

M_u = 119.65 kN-m 1M

b) ii) **Design a doubly reinforced beam 250 x 600 mm overall for a factored load of 300 kN-m at a particular section. Find area of steel required for beam. Assume d' = 50 mm, M20 concrete & F_e415.**

d'/d	**0.05**	**0.10**	**0.15**	**0.20**
f_{sc} (N/mm^2)	**355**	**352**	**342**	**329**

Ans. Given data :

b = 250 mm

D = 600 mm

d' = 50 mm

d = D – d' = 600 – 50

d = 550 mm

M20 $\Longrightarrow$ f_{ck} = 20 N/mm^2

F_e415 $\Longrightarrow$ f_y= 415 N/mm^2

To find Area of steel = A_{st} =?

<u>**Step 1:**</u> To find limiting moment of resistance M_{umax}:

M_{umax} = 0.138 $* f_{ck} *$ b $*$ d^2

M_{umax} = 0.138 x 20 x 250 x 550^2

M_{umax} = 208.725 x 10^6 N-mm

M_{umax} = 208.725 kN-m **1M**

As $M_u > M_{umax}$ .... Design the beam as doubly reinforced beam.

Step 2: To find Area of steel (A_{st1}):

P_{tlim} = 0.048 * f_{ck} .... For M20 & F_e415

P_{tlim} = 0.048 x 20

P_{tlim} = 0.96% **1M**

Therefore,

A_{st1} = (P_{tlim} * b * d) / 100 = (0.96 x 250 x 550)/100

A_{st1} = 1320 mm² **1M**

Step 3: Calculate Factored bending moment:

$M_{u2} = M_u - M_{u1}$ = 300 – 208.725

M_{u2} = 91.275 kN-m

Step 4: Calculate the value of f_{sc} & f_{cc}:

$f_{cc} = 0.45 * f_{ck} = 0.45 \text{ x } 20$

$f_{cc} = 9 \text{ N/mm}^2$ &

d' / d = 50/550

d' / d = 0.11

From given table,

d'/d	0.10	0.15
f_{sc} (N/mm²)	352	342

f_{sc} = 352 – {(352-342) x (0.11-0.10) / (0.15-0.10)}

f_{sc} = 350 N/mm² **1M**

Step 5: Taking moment about tensile steel:

$M_{u2} = (f_{sc} - f_{cc}) * A_{sc} * (d - d')$

91.275 x 10^6 = (350 – 9) * A_{sc} * (550 – 50)

$A_{sc} = 535.34 \text{ mm}^2$ **1M**

Provide 2-20 mm Ø bars, $A_{sc provided} = 628.32 \text{ mm}^2$

Step 6: Equating C_{u2} & T_{u2}:

$(f_{sc} - f_{cc}) * A_{sc} = 0.87 * f_y * A_{st2}$

$(350 – 9) \times 628.32 = 0.87 \times 415 \times A_{st2}$

A_{st2} = 593.43 mm²

Step 7: Calculate total area of steel required:

$A_{st} = A_{st1} – A_{st2} = 1320 + 593.43$

A_{st} = 1913.43 mm²

Therefore, provide 4 – 25 mm diameter bars as a main reinforcement. **1M**

Q. 5 **Attempt any TWO:** **16**

a) **Determine the ultimate moment resisting capacity of a beam. Take b = 250 mm, d = 450 mm, d' = 30 mm, A_{st} = 2450 mm², A_{sc} = 400 mm², f_{ck} = 20 N/mm², f_y = 415 N/mm², f_{sc} = 355 N/mm², & neglect f_{cc}.**

Ans. Given data :

b = 250 mm

d = 450 mm

d' = 30 mm

$A_{st} = 2450\ mm^2$

$A_{sc} = 400\ mm^2$

$f_{ck} = 20\ N/mm^2$

$f_y = 415\ N/mm^2$

$f_{sc} = 355\ N/mm^2$

$f_{cc} = 0$

Step 1: To X_{umax}:

$X_{umax} = 0.48 * d = 0.48 \times 450$

X_{umax} = 216 mm **2M**

Step 2: To find actual X_u:

$$A_{st2} = \frac{(f_{sc} - f_{cc}) * A_{sc}}{0.87 * f_y}$$

$$A_{st2} = \frac{(355 - 0) * 400}{0.87 * 415}$$

A_{st2} = 393.30 mm²

$A_{st1} = A_{st} - A_{st2} = 2450 – 393.30$

A_{st1} = 2056.70 mm²

2M

$$x_u = \frac{0.87 * f_y * A_{st1}}{0.36 * f_{ck} * b}$$

$$x_u = \frac{0.87 * 415 * 2056.70}{0.36 * 20 * 350}$$

X_u = 412.54 mm > X_{umax} = 216 mm . . . . Section is Over reinforced **2M**

Step 3: To find Ultimate moment of resistance M_u:

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

$M_u = 0.138 * f_{ck} * b * d^2 + (f_{sc} - f_{cc}) * A_{sc} * (d - d')$

$M_u = 0.138 \times 20 \times 250 \times 450^2 + (355 - 0) \times 400 \times (450 - 30)$

$M_u = 199.36 \times 10^6$ N-mm.

M_u = 199.36 kN-m **2M**

b) **A singly reinforced beam 230 x 450 mm deep (effective) is reinforced with 3 – 20 mm dia. of F_e415 bars to resist a factored shear force of 150 kN. Design 8 mm Ø two – legged vertical stirrups. Take τ_{Cmax} = 2.8 MPa. Use following table for τ_C.**

% P_t	**0.50**	**0.75**	**1.00**
τ_C in N/mm^2	**0.48**	**0.56**	**0.62**

Ans. Given data :

b = 230 mm

d = 450 mm

3-20 mm Ø bars,

$A_{st} = 3 \times \frac{\pi}{4} \times (20)^2$

A_{st} = 942.48 mm^2

V_u = 150 kN

F_e415 $\Longrightarrow$ f_y= 415 N/mm^2

τ_{Cmax} = 2.8 Mpa

To design 8 mm Ø 2-legged vertical stirrups

Step 1: Factored Shear force V_u:

V_u = 150 kN

Step 2: Calculate nominal Shear stress τ_v:

$\tau_v = V_u / b * d = (150 \times 10^3) / (230 \times 450)$

τ_v = 1.449 N/mm^2 **1M**

Check: $\tau_v = 1.449\ N/mm^2 < \tau_{Cmax} = 2.8$ Mpa . . . . **OK**

Step 3: Calculate Shear strength of concrete τ_c:

$P_t = (A_{st} / bd) * 100 = \{942.48 / (230 \times 450)\} \times 100$

$P_t = 0.91\%$

From given Table,

1M

% P_t	**0.75**	**1.00**
τ_c in N/mm^2	**0.56**	**0.62**

$\tau_c = 0.62 - \{(0.62 - 0.56) \times (1.00 - 0.91) / (1.00 - 0.75)\}$

$\tau_c = 0.598\ N/mm^2$

1M

As $\tau_v = 1.449\ N/mm^2 > \tau_c = 0.598\ N/mm^2$ . . . . Shear reinforcement is required

Step 4: Shear force for which shear reinforcement:

$V_{us} = V_u - \tau_c * b * d = (150 \times 10^3) - (0.598 \times 230 \times 450)$

$V_{us} = 88107$ N

1M

Design is only for vertical stirrups,

Therefore no bars are provided as a bent up bars. So, shear force resisted by vertical stirrups only.

$V_{usv} = V_{us} = 88107$ N

Provide 8 mm Ø 2-legged vertical stirrups

$S_v = (0.87 * f_y * A_{sv} * d) / V_{usv} = \{ 0.87 \times 415 \times \mathbf{(}2 \times \frac{\pi}{4} \times 8^2\mathbf{)} \times 450) / 88107$

$S_v = 185.38$ mm

Provide $S_v = 185.38$ mm say = 180 mm

1M

Step 5: Check for spacing S_v:

1. Minimum shear reinforcement

   $S_v \leq (0.87 * f_y * A_{sv}) / 0.4\ b = \{ 0.87 \times 415 \times \mathbf{(}2 \times \frac{\pi}{4} \times 8^2\mathbf{)} / 0.4 \times 230$

   $S_v \leq 394.53$ mm

1M

2. Maximum spacing = 0.75 d **or** 300 mm

   = 0.75 x 450 **or** 300 mm

   = 337.5 mm or 300 mm

1M

   Provide S_v minimum of 1 & 2

   S_v = 180 mm < minimum of 337.5 mm & 330 mm

1M

c) **Design a RC column footing for a column of size 400 x 400 mm. Take SBC of soil = 200 kN/m² & load on column is 1500 kN. Use M20 concrete & F_e415 Steel. Calculate depth of footing using bending moment criteria only.**

Ans. Given data :

b = 400 mm

P = 1500 kN

P_u = 1.5 x 1500

P_u = 2250 kN

SBC of soil = 200 kN/m^2

M20 $\Longrightarrow$ f_{ck} = 20 N/mm^2

F_e415 $\Longrightarrow$ f_y= 415 N/mm^2

To find:

1. Size of footing =?
2. Main steel in both direction =?

Step 1: Ultimate Bearing Capacity of soil:

U. B. C. (q_u) = 2 x SBC = 2 x 200

q_u = 400 kN/m^2

1M

Step 2: Calculate size of footing:

Assuming 5% as self-weight of footing

Area of footing = (Factored Load / UBC of soil)

= (1.05 x 2250) / 400

A_f = 5.906 m²

L = B = $\sqrt{A_f} = \sqrt{5.906}$

L = B = 2.43 m

say L = B = 2.5 m

1M

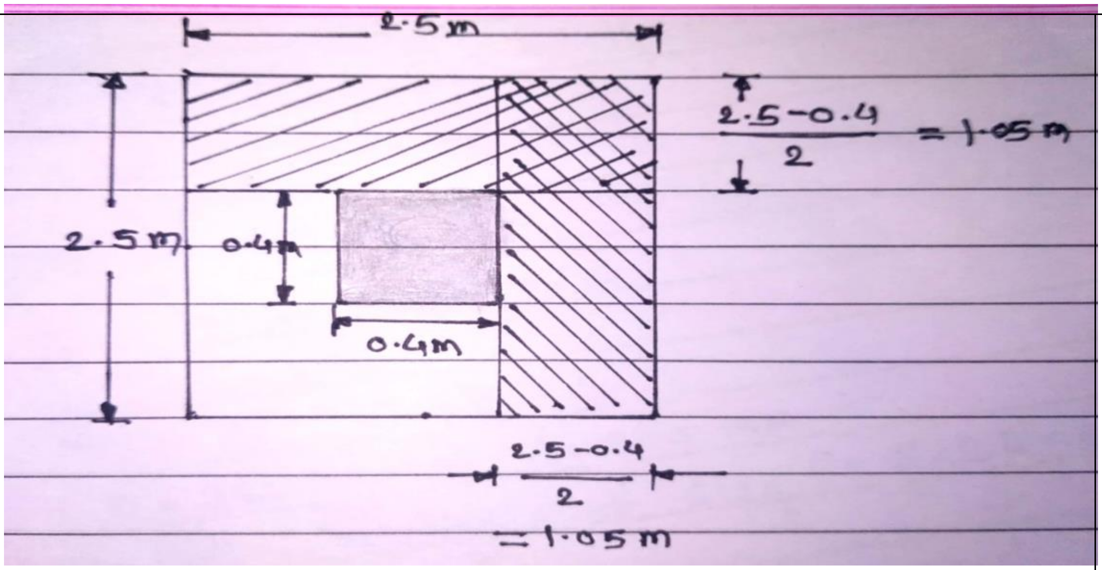
Adopt footing of size 2.5 m x 2.5 m

Step 3: Calculate Upward soil pressure (p):

p = (P_u / L x B) = (2250 / 2.5 x 2.5)

p = 360 kN/m²

1M



Step 4: Calculate depth of footing: **1M**

$M_x = M_y = 1 * X_1 * p * (X_1/2) = 1 \times 1.05 \times 360 \times (1.05/2)$

$M_x = M_y = 198.45$ kN-m

$d_{req.} = \sqrt{(M_x/0.138 * f_{ck} * b)} = \sqrt{(198.45 \times 10^6/0.138 \times 20 \times 1000)}$

$d_{req.}$ =268.14 mm **1M**

Say $d_{req.}$ =270 mm

Adopt cover of 50 mm

D = d + 50 = 270 + 50

D = 320 mm

Provide D = 320 mm & d = 270 mm

That is provide **size of footing as (2.5 m x 2.5 m x 0.32 m)**

Step 5: Calculate area of steel :

$$A_{stx} = A_{sty} = \frac{0.5 * f_{ck}}{f_y}\left\{1 - \sqrt{1 - \frac{4.6 * M_{dx}}{f_{ck} * b * d^2}}\right\}(b * d)$$

$$A_{stx} = A_{sty} = \frac{0.5 * 20}{415}\left\{1 - \sqrt{1 - \frac{4.6 * 198.45 * 10^6}{20 * 1000 * 270^2}}\right\}(1000 * 270)$$ **1M**

A_{stx} = A_{sty} **= 2527.82 mm²**

Using 16 mm diameter bars,

$$S_x = S_y = \frac{1000 * A_\phi}{A_{st}}$$

$$S_x = S_y = \frac{1000 * \frac{\pi}{4} * 16^2}{2527.82}$$

S_x = S_y = 79.50 mm

S_x = $S_y \cong$ **75 mm**

1M

Provide #16 mm @ 75 mm c/c both ways.

Step 6: Find development length of bars:

$$L_d = \frac{0.87 * f_y * \phi}{4 * \tau_{bd}}$$

$$L_d = \frac{0.87 * 415 * 16}{4 * 1.92}$$

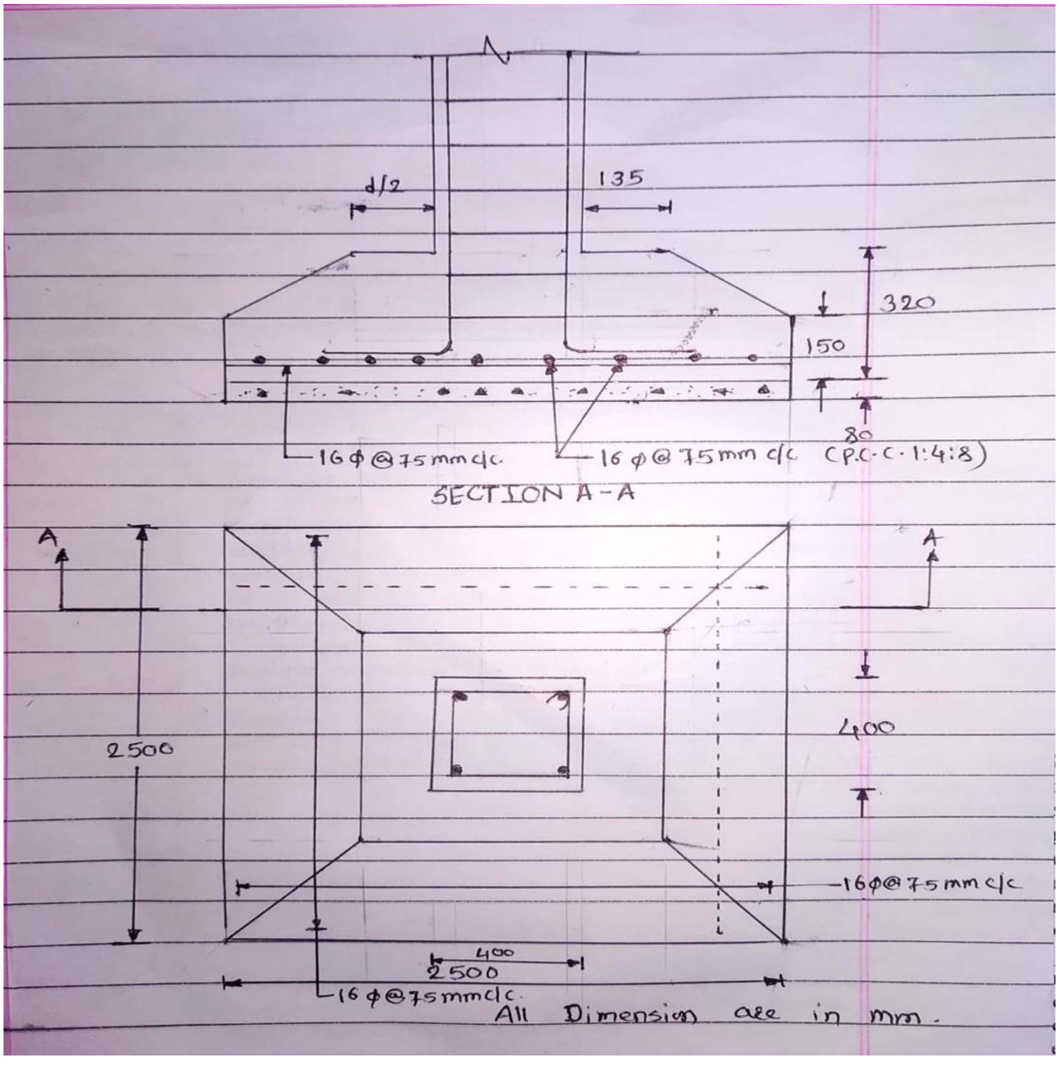
$L_d =$ **752.19 mm**

1M

Say $L_d =$ **760 mm**

This length is available from face of column.

Provide 320mm depth near the face of column and reduce depth of footing 150mm at the edge.



Q. 6 **Attempt any FOUR:** **12**

a) **State IS specifications for longitudinal & Transverse steel for column.**

Ans. **IS specification 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 steel in column

Max % of steel = 6 % of gross cross sectional area of column

V. maximum steel in column

Min % of steel = 0.8 % of gross cross sectional area of column

1 Mark each (any two)

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.

1M

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

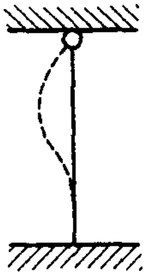
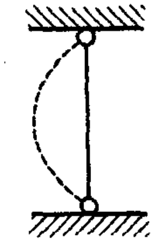
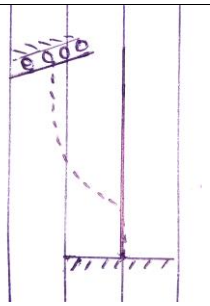
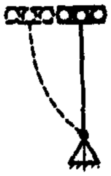
1M

b) **State effective length for any four end conditions of column with neat sketch.**

Ans.

Sr. No.	End Conditions	Schematic Representation	Effective length
01	Effectively held in position and restrained against rotation in both ends.		**0.65 L**

4M Any 4 with neat sketch

02	Effectively held in position at both ends, restrained against rotation in one end.		**0.80 L**
03	Effectively held in position at both ends, but not restrained against rotation.		**1.00 L**
04	Effectively held in position and restrained against rotation at one end, and at the other end restrained against rotation but not held in position.		**1.20 L**
05	Effectively held in position and restrained against rotation at one end, and at the other end partially restrained against rotation but not held in position.		**1.50 L**
06	Effectively held in position at one end but not restrained against rotation, and at the other end restrained against rotation but not held in position.		**2.00 L**
07	Effectively held in position and restrained against rotation at one end but not held in position nor restrained against rotation at the other end		**2.00 L**

	c) **Ans.**	**Explain – ‘over reinforced sections are not permitted as per IS codes”.** 1) In over-reinforced section, percentage of steel is more than critical percentage. 2) Due to this, the concrete crushes reaching its ultimate strain firstly before steel reaching its yield point. 3) In this case, the beam will fail initially due to overstress in the concrete, suddenly without giving any warning. 4) Therefore, design codes restrict the percentage of steel in RC sections to that of balanced section thus disallowing over- reinforced section.	**1M** **1M** **1M** **1M**	
	d) **Ans.**	**Define Nominal Cover. Why cover is provided?** **Nominal cover:** It is defined as the distance measured from the concrete surface to the nearest surface/edge of the reinforcing bar. **Purposes of providing cover to reinforcement:** 1) To prevent corrosion of steel. 2) To give necessary embedment to the reinforcing bar.	**2M** **2M**	
	e) **Ans.**	**For a T-beam with following dimensions:** **Width of flange = 1500 mm** **Width of web = 300 mm** **Effective depth = 500 mm** **Depth of slab = 120 mm** **Tension steel = A_{st} = 2000 mm^2** **Materials = M20- F_e415** **Calculate ultimate moment of resistance of the section.** Given data : b_f = 1500 mm b_w = 300 mm d = 500 mm D_f = 120 mm A_{st} = 2000 mm^2 M20 $\Longrightarrow$ f_{ck} = 20 N/mm^2 F_e415 $\Longrightarrow$ f_y= 415 N/mm^2		

		To find ultimate moment of resistance = M_u = ?		
		Step 1: Calculate neutral axis depth x_u:		
		$0.36 f_{ck} * b_f * x_u = 0.87 f_y * A_{st}$		
		$0.36 * 20 * 1500 * x_u = 0.87 * 415 * 2000$		
		$x_u =$ **66.851 mm** < D_f = 120 mm	**1M**	
		x_{umax} = 0.48 d		
		= 0.48 x 500		
		x_{umax} = 240 mm	**1M**	
		$x_u < x_{umax}$ . . . . **Section is under reinforced**		
		Step 2: Calculate Ultimate moment of resistance M_u:		
		$M_u = T_u * Z_u$		
		$M_u = 0.87 * f_y * A_{st} * (d - 0.42 * x_u)$	**1M**	
		$M_u = 0.87 * 415 * 2000 * (500 - 0.42 * 66.851)$		
		$M_u = 340.77 \times 10^6$ N-mm		
		M_u = 340.77 kN-m	**1M**	