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 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 judgement 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.
8) As per the policy decision of Maharashtra State Government, teaching in English/Marathi and Bilingual (English + Marathi) medium is introduced at first year of AICTE diploma Programme from academic year 2021-2022. Hence if the students in first year (first and second semesters) write answers in Marathi or bilingual language (English +Marathi), the Examiner shall consider the same and assess the answer based on matching of concepts with model answer.

Q. No.	Sub Q. N.	Answer	Marking Scheme
Q-1		**Attempt any FIVE of the following:**	**10 M**
	a)	**Write the justification to the safety factor which is used in limit state design is referred as a partial factor of safety.**	**2M**
	Ans.	Since the safety of principal design factors (viz. load and material strengths) which are not dependent on each other, two different safety factors, one for load and other for material strength are used. Because each of two factors contributes partially to safety, they are termed as partial safety factors.	2M
	b)	**State any loads to be considered while designing steel structures along with their respective is codes.**	**2M**
	Ans	1. Dead load – IS875:1987 Part-I 2. Live load - IS875:1987 Part-II 3. Wind load - IS875:1987 Part-III 4. Snow load - IS875:1987 Part-IV 5. Load due to Seismic force- IS 1893:2002 & IS875:1987 Part-V	**½ M Each (any four)**
	c)	**State any two difference between simply supported slab and cantilever slab**	**02**
	Ans	(see table below)	**2M (1 M Each)**

S N	Simply Supported Slab	Cantilever slab
1	Main R/f is provided at bottom side of section	Main R/f is provided at top side of section
2	Both ends of slab are simply supported.	One ends of slab is fixed and other is free.
3	Bending moment is maximum at center of section.	Bending moment is maximum at fixed end.
4	Bending moment pattern is sagging across c/s	Bending moment pattern is hogging across c/s
5	Example- slab of hall or bedroom	Example- chajjas, overhang balcony.

	d)	**Give expression for development length along with the notations used in it.**	**02**
		Development length is calculated using following expression $L_d = \frac{0.87\ Fy\ \emptyset}{4x\ T_{bd}}$ F_y =Grade of steel τ_{bd} = Design bond stress L_d = Development length Φ= Dia. of bar	**1M** **1 M**
	e)	**Enlist any four functions of using transverse Steel in RCC column**	**02**
	Ans	i) To prevent buckling of longitudinal reinforcing bars. ii) To hold longitudinal reinforcement in position. iii) To confine the concrete core. iv) To resist diagonal tension.	**½ M Each**
	f)	**Define the characteristics load and design load.**	**02**
	Ans	**Characteristic Load -**Characteristic Load means that value of load which has 95% probability of not being exceeded during the life of the structure. **Design Load**- Partial Safety factor for load is load enhancing factor (greater than one) which when multiplied to characteristic load gives a load known as Design Load Design of Load (Fd) = Partial Safety factor for load x characteristic load	1M **1M**
	g)	**Define the terms, end return and lap length used in welding connections along with their specification as recommended by IS 800:2007.**	**02**
	Ans	1. **End Return:**End returns are made equal twice the size of weld to relieve the weld length from high stress concentration at their ends **Specification**: End return should not less than twice the size of the weld. 2. **Lap Length**: the length that is needed for overlapping of two steel plates so they act like a single member. **Specification:** In the case of lap joints, the minimum lap should not be less than four times the thickness of the thinner part joined or 40 mm, whichever is more.	**½ M** **½ M** **½ M** **½ M**

Q.2		**Attempt any THREE of the following:**	**12 M**
	a)	**State for benefits when steel is used as a construction material. Also list any four steel structure along with their function.**	4
	Ans	1) The steel member can resist high load with comparatively light weight and small size of member 2) Extensively useful for large span industrial steel bridges, Tower and communication networks, steel overhead tanks 3) Steel has many good mech. Properties like ductility and malleability 4) It is good for earthquake resistant structure due to more ductile nature. 5) It gives high scrap value 6) It is easy to fabricate by bolting or welding to any desired shape. 7) The steel member are gas and water tight 8) The steel member have long service life 9) It bears tension, compression , shear, bending and torsional forces 10) The steel structures may be inspected quickly and conveniently 11) Steel as construction material can be recycled easily (reuse) List of steel structure 1. Communication towers. 2. Steel water tanks 3. Steel bridges. 4. Gantry girders and cranes. 5. Steel columns 6. Steel Chimney 7. Building frames	½ M Each (Any four) ½ M Each (Any four)
	b)	**Derive the neutral axis coefficient and moment of resistance constant for a singly reinforced balance section having effective depth ‘d’ and width ‘b’. Use M20 concrete mix and Fe 415 Steel**	4M
	Ans	**Given :- Dimension- b and d, Fy = 415 Mpa , Fck = 20 Mpa** **1. Neutral axis coefficient** Xu max = $\frac{700\,d}{1100+0.87\,Fy}$ = $\frac{700\,d}{1100+0.87\,x\,415}$ = 0.479 d **2. Moment of Resistance**	2M

		$Mu\ max = 0.36\ Fck \times \frac{Xu\ max}{d} \times (1 - \frac{0.42\ Xu\ max}{d}) \times b\ d^2$ $= 0.36 \times 20 \times \frac{0.497\ d}{d} \times (1 - \frac{0.42 x\ 0.479 d}{d}) \times b\ d^2$ $= 2.75\ b\ d^2$	2 M
	c)	**Diameter of steel is 20 mm, Steel grade fe415 and bond stress 1.2 Mpa for plain bars in tension, calculate the development length for bars in compression.**	**4M**
	Ans.	Given: Φ = 20mm f_{ck} = 20 N/mm^2 f_y = 415N/mm^2 Bond stress, τbd =1.2 N/mm^2 **Development length for bar in compression** T_{bd} for TOR(HYSD) steel = 1.2 x 1.6 x 1.25 = 2.4 Mpa $Ld = \frac{0.87\ Fy\ \emptyset}{4x\ T_{bd}}$ $= \frac{0.87x\ 415\ x\ 20}{4x\ 2.4}$ = 752.18 mm	**1 M** **1 M** **1M** **1 M**
	d)	**A Rectangular RC beam of effective section 230 mm wide and 400 mm Deep is reinforced with 3 bars of 16 mm diameter. Determine the shear resistance of concrete section, if beam carries ultimate shear of 80 kN. Use M20 concrete of Fe415 Steel. Take, permissible shear stress in concrete equal to 0.53 N/mm^2.**	**4M**
	Ans.	Given,:-b = 230 mm, d = 400 mm, F_{ck} = 20 N/mm^2 . τ_c = 0.53 N/mm^2 $A_{st} = 3 \times \pi/_4 \times 16^2$ =603.18 mm^2 V_u =80 kN. Shear resistance of concrete = τ_c x b x d = 0.53 x 230 x 400 = 48.76 x 10^3 N	**1 M** **1 M** **1 M** **1 M**

Q. No.	Sub Q.N.	Answer	Marking Scheme
Q-3		**Attempt any TWO of the following:**	**12**
	a)	**Determine the efficiency of Lap joint used to connect two plates of 10 mm thick. Use, Fe 410 grade for plate material and 4.6 grade for bolts. Take, the end distance equal to 30 mm and bolt diameter 20 mm with 50 mm pitch.**	**06M**
	Ans.	**Given Data** t = 10 mm Fe410 $f_y = 410\ N/mm^2$ 4.6 Grade of bolt $f_{ub} = 400\ N/mm^2$ e = 30 mm d = 20 mm $d_o = 20 + 2 = 22\ mm$ p = 50 mm **Step 1) Bolt Value or Strength of bolt** = Smaller of i) and ii) i) Strength of bolt in shearing (V_{dsb}) $$V_{dsb} = \frac{V_{nsb}}{\gamma_{mb}}$$ Assume $\gamma_{mb} = 1.25$ Also assume shear plane is intercepting at thread portion only and here is a single shear. $$\therefore n_n = 1\ \&\ n_s = 0$$ $$A_{nb} = 0.78\ x\ \frac{\pi}{4} d^2$$ $$A_{nb} = 0.78\ x\ \frac{\pi}{4} 20^2$$ $$\boldsymbol{A_{nb} = 245.044\ mm^2}$$ $$V_{nsb} = \frac{f_{ub}}{\sqrt{3}} [n_n * A_{nb} + n_s * A_{sb}]$$ $$V_{nsb} = \frac{400}{\sqrt{3}} [1\ x\ 245.044 + 0]$$ $V_{nsb} = 56.59\ x\ 10^3\ N$ = 59.59 KN $$V_{dsb} = \frac{56.59}{1.25}$$ $$\boldsymbol{V_{dsb} = 45.272\ kN}$$ **OR**	½ M 1M

		V_{dsb} = **0.462** f_{ub} n_n A_{nb} n_n = 1 ----------- for Single Shear V_{dsb} = 0.462 x 400 x 1 x 245.04 = 45.28 x 10^3 N = **45.272 KN** ii) Strength of bolt in bearing (V_{dpb}) $$V_{dpb} = \frac{V_{npb}}{\gamma_{mb}}$$ $$V_{npb} = 2.5\, k_b * d * t * f_u$$ Where, K_b = Smaller of ($\frac{e}{3d_o}$, $\frac{p}{3d_o} - 0.25$, $\frac{f_{ub}}{f_u}$, 1.0) K_b = Smaller of ($\frac{30}{3x\,22}$, $\frac{50}{3\,x\,22} - 0.25$, $\frac{400}{410}$, 1.0) = 0.454 $$V_{npb} = 2.5\,x\,0.454\,x\,20\,x\,10\,x\,410$$ $$V_{npb} = 93.07\,x\,10^3\,N$$ $$V_{npb} = 93.07\,kN$$ $$V_{dpb} = \frac{V_{npb}}{\gamma_{mb}} = \frac{93.07}{1.25}$$ $$\boldsymbol{V_{dpb} = 74.456\,kN}$$ **OR** V_{dpb} = 2 x $k_b\, d\ t_p\ f_u$ = 2 x 0.454 x 20 x 10 x 410 = 74.456 x10^3 N **= 74.456 KN**	**1M**
		Bolt Value for single bolted joint = 1 x Smaller of i) and ii) **= 45.272 KN**	**½ M**
		Step 2 Strength of plate in tearing per pitch length (Tdn) $$T_{dn} = \frac{0.9\,f_u(p - d_o)t}{\gamma_{ml}}$$ **OR** = 0.72 f_u x (P – n dh) tp **=** 0.72 x 410 x (50 – 1 x 22) x 10 =**82.656 KN**	**½ M**
		Step3) Strength of joint = Smaller of Step 1) and Step 2) = **45.272 KN**	**½ M**
		Step 4) Strength of Solid Plate Design Strength of solid plate per pitch length = $\frac{0.9 * f_u * p * t}{\gamma_{ml}}$ or 0.72 f_u P tp = 0.72 X 410 X 50 X 10 = **147.60 KN**	**1M**

Step 5) Efficiency of the joint

$$\text{Efficiency } (n) = \frac{\text{Strength of Joint}}{\text{Strength of solid plate}} \times 100$$

$$\text{Efficiency } (n) = \frac{45.272}{147.60} \times 100$$

1M

$$= \mathbf{30.67}\ \%$$

b) **Define the under-reinforced, over-reinforced and balanced sections used in RC design and also state which section is preferred and why. Draw a labeled sketch of stress block diagram for a singly reinforced RCC section by showing important parameters on it.** **06M**

Ans.

a) **Under reinforced section-** When the percentage of steel provided in section is less than pt limit then section is known as under reinforced section.

$$X_u < X_{umax}$$

b) **Over reinforced section-** When the percentage of steel provided in section is more than pt limit. Then section is known as over reinforced section. **1M**

$$X_u > X_{umax}$$

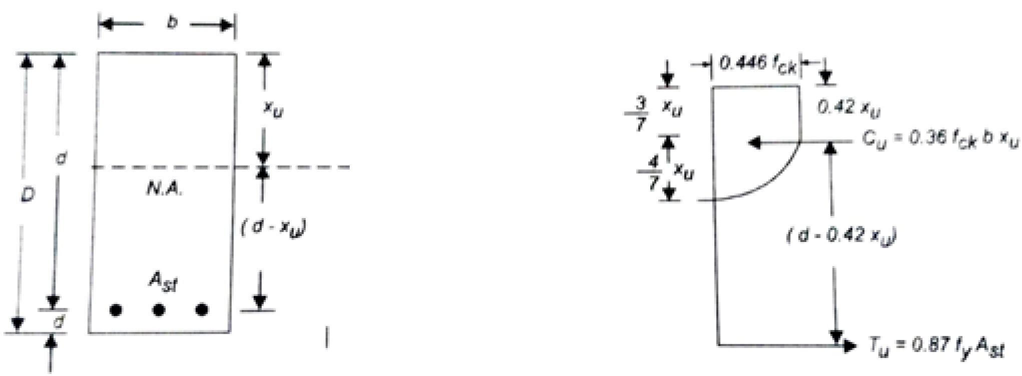
c) **Balanced Section-** in balanced section **1M**

$$P_t = P_{t\,lim.}$$
$$X_u = X_{umax}$$

When the ratio of steel in concrete in a section in such that maximum strain in steel and maximum strain in concrete reach their maximum value simultaneously, the section is referred to as balanced section or critical section.

Which section is preferred and why? **1M**

The under reinforced sections are preferred over the other two as in under reinforced section, steel will yield first before concrete crushes which results into the deformation of member giving the sign or warning before the failure. **1M**



2M

Let b = width of the section
D = overall depth of section
d = effective depth of section = D – d'
d' = effective cover

		Xu = depth of neutral axis from compression face Ast = Area of tension steel Pt = % of steel Zu = lever arm = (d – 0.42 Xu)	
	c)	**Calculate the lap of one plate having size 120 mm x 10 mm over the another plate of size 180 mm x 12 mm which transmits a pull equal to full strength of smaller plate. Assume, fillet weld of 6mm size and welding is operated on three sides on the field. Use, yield stress as 250 MPa whereas ultimate stress equal to 410 MPa in steel.**	**06M**
	Ans.	Given Data Size of plate 1) 120 x 10 mm t_1 = 10 mm Size of plate 2) 180 x 12 mm t_2 = 12 mm t = 10 mm	**1 M**
		Size of weld s = 6 mm, Welding is provided on 3 side (Field weld) $f_y = 250\ MPa$ and $f_u = 410\ N/mm^2$	
		1) Calculate Pu $p_u = \frac{f_y\ x\ A_g}{\gamma_{mo}}$ = 0.91 Fy A--- for design of joint for full strength of plate = 0.91 Fy x b x tp = 0.91 x 250 x 120 x10= 273 x10^3 N	**1M**
		2) Size of Weld (S) Use Size of Weld (S) = 6 mm ----------------given	**½ M**
		3)Design strength of weld per mm length (Pw) Pw = 0.7x S x Fwd ----------------- N/mm For field weld , Fwd =0.385Fu Pw = 0.7 x 6 x 0.385 x 410 = 662.97 N/mm	**1M**
		3) Effective Length of weld required Length of Weld (l) = $\frac{Factored\ Axial\ Force\ \ or\ Full\ strength\ of\ plate}{Pw}$ = 273 x10^3 / 662.97 = 411.78 mm = 415 mm (say)	**1M**
		4) Distribution of Weld Length Welding on Three Sides	

Total length of weld (l) = $l_1 + l_2 + l_3$

l_3 = b = 120 mm (width of plate)

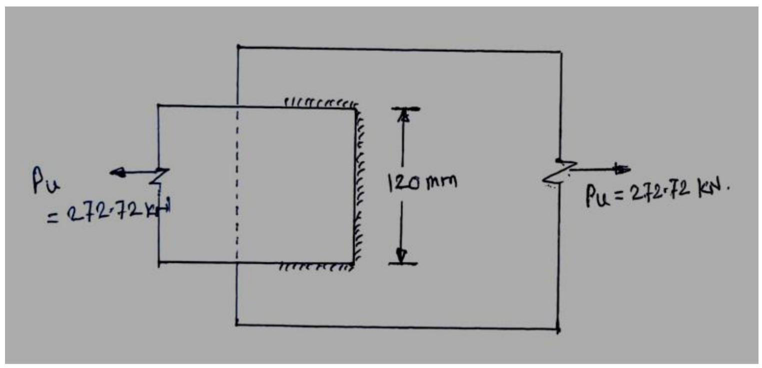
415 = $l_1 + l_2 + 120$

$l_1 + l_2 = 415-120$ **1M**

$l_1 = l_2 = \frac{415-120}{2}$ = 147.5mm

= 150 mm (say)

Minimum Lap = $\mathbf{150\ mm}$



½ M

Q-4		**Attempt any TWO of the following:**	**12**
	a)	**A rectangular beam 250 mm wide and 550 mm deep with effective cover of 50 mm is used as simply supported beam of span 5 m. Calculate the central point load neglecting the self-weight of beam can carry, if it is reinforced by 4-bars of 20 mm diameter. Use, M20 grade of concrete mix and Fe415 steel grade.**	**06M**

Ans.

STEP 1) Given Data

b = 250 mm

D = 550 mm, $d_c = 50\ mm$

d = 550 – 50

d = 500 mm

4 # 20 mm dia. Bars are used.

$$A = n\ \frac{\pi}{4}\ x\ d^2$$

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

$$\boldsymbol{A = 1256.64\ mm^2}$$

1M

M20 $f_{ck} = 20\ MPa$

Fe415 $f_y = 415\ MPa$

STEP 2) Calculate Limiting Neutral axis depth (x_{umax})

For Fe415; $x_{umax} = 0.479\ d$

$$x_{umax} = 0.479\ x\ 500$$

1M

$$\boldsymbol{x_{umax} = 239.5\ mm}$$

STEP 3) Calculate actual Neutral axis depth (x_u)

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

$$x_u = \frac{0.87\ x\ 415\ x\ 1256.64}{0.36\ x\ 20\ x\ 250}$$

$$\boldsymbol{x_u = 252.06\ \text{mm}}$$

1M

STEP 4) Compare x_u with x_{umax}

$$\boldsymbol{x_u > x_{umax}}$$

252.06 mm > 239.5 mm

1M

…. Section is over reinforced

As over reinforced section is not allowed

STEP 5) Calculate limiting moment of resistance

$$\boldsymbol{M_u = M_{ulim}}$$

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

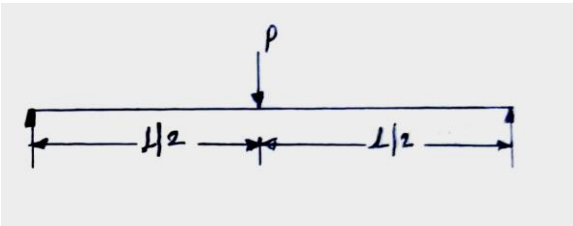
$$M_u = 0.138\ x\ 20\ x\ 250\ x\ 500^2$$

1M

$$M_u = 172.5\ x\ 10^3\ Nmm$$

$$\boldsymbol{M_u = 172.5\ kNm}$$

STEP 6) Calculate Point load



SKETCH

$$M_{max} = \frac{Pu\ l}{4}$$

$$\frac{Pu\ l}{4} = 172.5$$

$$Pu = \frac{172.5\ x\ 4}{5}$$

1M

$$\boldsymbol{Pu = 138\ kNm}$$

	b)	**A RCC beam with 230 mm wide is used as a cantilever of span 4m and carrying u. d. l. of 5 kN/m throughout the span. Design the singly reinforced beam using M20 concrete and Fe415 steel.**	06

Ans.

Note: Above question is out of syllabus.

STEP 1) Given data:

b = 230 mm

$l_{eff} = 4\,m$ … Assuming given span as effective span.

$w = 5$ kN/m

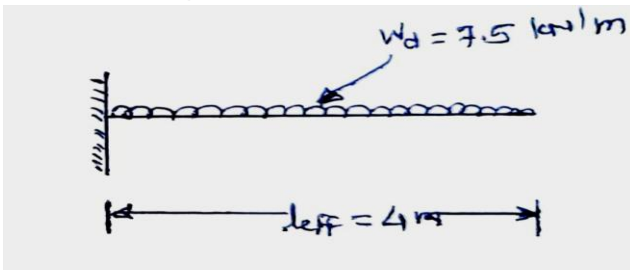
$W_d = 1.5\,x\,5$

$W_d = 7.5$ kN/m

M20 $f_{ck} = 20\,MPa$

Fe415 $f_y = 415\,MPa$ **1M**

STEP 2) Find factored bending moment:



SKETCH

$$M_u = \frac{w_d * {l_{eff}}^2}{2}$$

$$M_u = \frac{7.5\,x\,4^2}{2}$$

$$\boldsymbol{M_u = 60\,kNm}$$ **1M**

STEP 3) Calculate depth of section:

For Fe415

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

Equating M_u with M_{ulim}

$$\therefore \quad M_{ulim} = M_u$$

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

$$0.138 * 20 * 230 * d^2 = 60\,x\,10^3$$

$$d = 307.43\,mm$$

$$\boldsymbol{Say\ d = 310\ mm}$$ **1M**

Assuming effective cover as 40 mm; Overall depth will be

$$D = d + d'$$

$$D = 310 + 40$$

$$\boldsymbol{D = 350\,mm}$$ **1M**

STEP 4) Find area of steel A_{st}:

$$\boldsymbol{Pt_{lim} = 0.96\%}$$ ……. For M20 & Fe415

$$Pt_{lim} = \frac{A_{st}}{b * d}\ x\ 100$$

$$\frac{A_{st}}{b * d}\ x\ 100\ =\ 0.96$$

$$A_{st} = \frac{0.96}{100}\ x\ b\ x\ d$$

$$A_{st} = \frac{0.96}{100}\ x\ 230\ x\ 310$$

$$\boldsymbol{A_{st} = 684.48\ mm^2}$$

STEP 5) Calculate No. of bars assuming 20 mm bar diameter **1M**

$$n = \frac{684.48}{\frac{\pi}{4} x\ 20^2}$$

$$n = \frac{684.48}{314.16}$$

$$n = 2.17$$

$$\boldsymbol{Say\ n = 3\ bars}$$

$$\therefore\ Provide\ 3\ bars\ of\ 20\ mm\ diamter\ on\ tension\ side$$ **1M**

c) **Calculate the spacing of 6 mm diameter mild steel of two legged vertical stirrups for a simply supported beam of span 3.6 m with 230 mm x 350 effective in cross-section. The beam is reinforced with 4-bars of 12 mm diameter on tension side and are continued into supports of grade Fe415. The beam is carrying total u. d. l. of 24 kN/m over entire span. Assume M20 concrete mix. Draw a cross-section showing reinforcement details. Use, table if necessary for shear strength of concrete mix (τ_c).** **06M**

% p_t	0.25	0.50	0.75	1.00
ζ_c in N/mm^2	0.36	0.48	0.56	0.62

Ans.

STEP 1) Given Data

b = 230 mm

d = 350 mm

Assume given span as effective span $l_{eff} = 3.6\ m$

$$w = 24\ kN/m$$

$$w_d = 1.5\ x\ 24$$

$$\boldsymbol{w_d = 36\ kN/m}$$

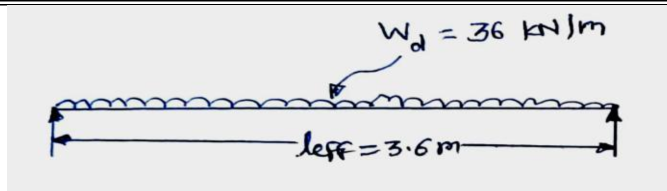
Fe415 $f_y = 415\ MPa$

6 mm dia. Mild steel ($f_y = 250\ MPa$) and two legged stirrups

4#12 mm dia. Bars on tension side

$$A_{st} = n\ x\ \frac{\pi}{4} d^2 = 4\ x\ \frac{\pi}{4} 12^2$$

$$\boldsymbol{A_{st} = 452.39\ mm^2}$$



SKETCH

STEP 2) Calculate shear force (V_u)

$$V_u = \frac{w_d \; x \; l_{eff}}{2}$$
$$V_u = \frac{36 \; x \; 3.6}{2}$$
$$V_u = \frac{36 \; x \; 3.6}{2}$$
$$\boldsymbol{V_u = 64.8 \; kN}$$

STEP 3) Calculate nominal shear stress (τ_v)

$$\tau_v = \frac{V_u}{b * d}$$
$$\tau_v = \frac{64.8 \; x \; 10^3}{230 \; x \; 350}$$

1M

$$\boldsymbol{\tau_v = 0.805 \; N/mm^2} < \tau_{cmax} = 2.8 \; N/mm^2$$

STEP 4) Calculate shear strength of concrete (ζ_c)

$$P_t = \frac{A_{st}}{b * d} \; x \; 100$$
$$P_t = \frac{452.39}{230 \; x \; 350} \; x \; 100$$

1M

$$\boldsymbol{P_t = \; 0.562} \; \%$$

	$\boldsymbol{P_t = \; 0.562}$ %	
% $\boldsymbol{p_t}$	$\boldsymbol{p_{t1} = 0.50}$	$\boldsymbol{p_{t2} = 0.75}$
$\boldsymbol{\tau_c}$ in $\boldsymbol{N/mm^2}$	$\boldsymbol{\tau_{c1} = 0.48}$	$\boldsymbol{\tau_{c2} = 0.56}$

By interpolation

$$\boldsymbol{\tau_c = \tau_{c1} + (p_t - p_{t1}) \frac{(\tau_{c2} - \tau_{c1})}{p_{t2} - p_{t1}}}$$

$$\boldsymbol{\tau_c = 0.48 + (0.562 - 0.50) \frac{(0.56 - 0.48)}{0.75 - 0.50}}$$

1M

$$\boldsymbol{\tau_c = 0.499 \; N/mm^2}$$

STEP 5) Compare τ_v & τ_c

$$\tau_v > \tau_c$$

$0.805 \; N/mm^2 > 0.499 \; N/mm^2$ …..Provide additional shear reinforcement

STEP 6) Calculate additional shear force required (V_{us})

$$V_{us} = V_u - \tau_c bd$$

1M

		$V_{us} = (64.8\ x\ 10^3) - (0.499\ x\ 230\ x\ 350)$ $\boldsymbol{V_{us} = 24.63\ x\ 10^3\ N}$ As no bars are bent hence the additional shear force will be resisted vertical stirrups only. $\boldsymbol{V_{usv} = V_{us} = 24.63\ x\ 10^3\ N}$ **STEP 7) Calculate between the stirrups (S_v)** $S_v = \frac{0.87 * f_y * A_{sv} * d}{V_{usv}}$ $S_v = \frac{0.87 * 250 * 2\ x \frac{\pi}{4} x\ 6^2\ x\ 350}{24.63\ x\ 10^3}$ $\boldsymbol{S_v = 174.77\ mm}$	1M
		STEP 8) Check for minimum shear reinforcement $S_v = \frac{0.87 * f_y * A_{sv}}{0.4b}$ $S_v = \frac{0.87 * 250 * 2\ x \frac{\pi}{4} x\ 6^2}{0.4\ x\ 230}$ $\boldsymbol{S_v = 133.68\ mm}$ **STEP 8) Check for maximum spacing** $S_v \ngtr 0.75\ d\ or\ 300\ mm$ $S_v \ngtr 0.75\ x\ 350\ or\ 300\ mm$ $S_v \ngtr 262.5\ or\ 300\ mm$ $\therefore \boldsymbol{Provide\ 6\ mm - 2\ legged\ vertical\ stirrups\ @\ 170\ mm\ c/c}$	1M

Q. No.	Sub Q.N.	Answers	Marking Scheme
Q-5		**Attempt any TWO of the following:**	**12M**
	a)	**Design a simply supported RC Slab for a Hall 3.8 m x 12 m clear dimensions is supported on wall 230 mm wide all around. The Slab is subjected to live load of 3 kN/m² along with finishing load of 1 kN/m². Use M20 concrete mix and Fe415 steel grade. No checks are allowed for the design and use modification factor equal to 1.4. Draw sketch of cross section showing reinforcement details along shorter span only.**	**6M**
		Lx = 3.8 m, Ly = 12 m, t = 230 mm, m, Live Load = 3 kN/m², Finishing load 1 kN/m², M-20, Fe-415, M.F. = 1.4. **Step 1) Span and Aspect ration** l_x = Clear span (Lcx) + t = 3.8 + 0.23 = 4.03 m and l_y = Clear Span (Lcx) + t = 12+0.23 = 12.23 m Aspect ratio = $\frac{Ly}{Lx}$ = $\frac{12.23}{4.03}$ = 3.03 > 2 , That is One Way Slab **Step 2) Trial Depth** d $_{provided}$ = $\frac{lx}{20 \text{ x M.F}}$ = = $\frac{4030}{20 \text{ x } 1.4}$ = 143.92 mm = 145 mm (Say) Assume d' = 20 mm**(Note: Students may assume different cover)** Overall (D) = d + d' = 145 + 20 = 165 mm **Step 3) Revise Effective Span** Effective Span (l_x) = Minimum of i) Lcx + d , ii) Lcx + t = Minimum of i) 3.8 +0.145 ii) 4.03 m = 3.945 m **Step 4) Load calculation** Consider 1 m wide strip of slab (b= 1 m or 1000 mm) a) Self-wt. (DL) = 25 b D = 25 x1x D = 25 x0.165= 4.125 KN/m b) Floor Finish FF = 1 x 1 = 1 KN/m c) Live Load (LL) = 3 x 1 = 3KN/m Total Working Load (W) = 8.125 KN/m Total Ultimate or Factored Load (Wu) = 1.5 x 8.125 = 12.1875 KN /m **Step 5) Design Moment (Mu)** Mu = $\frac{Wu\, l^2}{8}$ -------For Simply Supported Slab at Mid span = $\frac{12.1875 \text{ x } 3.945^2}{8}$ = 23.709 KN.m = 23.709 x 10^6 N.mm	½ M ½ M ½ M ½ M ½ M

Step 6) Check for Concrete depth ½ M

$$d_{req} = \sqrt{\frac{Mu}{0.138\, Fck\, b}} \text{ ------------- for Fe 415}$$

$$= \sqrt{\frac{23.709 \times 10^6}{0.138 \times 20 \times 1000}}$$

$$d_{req} = 92.68 \text{ mm} < d_{Provided} \quad \text{Hence O.K}$$

Step 7) Main steel :-

Reinforcement along short span

$$Ast = \frac{0.5\, Fck\, b\, d}{Fy}\left[1 - \sqrt{1 - \frac{4.6\, Mu}{Fck\, bd^2}}\right]$$ ½ M

$$Ast = \frac{0.5 \times 20 \times 1000 \times 145}{415}\left[1 - \sqrt{1 - \frac{4.6 \times 23.709 \times 10^6}{20 \times 1000 \times 145^2}}\right]$$

$$= 487.04 \text{ mm}^2$$

$$Ast\ min = \frac{0.12}{100} \times b \times D = \frac{0.12}{100} \times 1000 \times 165 = 198 \text{ mm}^2$$

$Ast > Ast_{min}$ Hence O.K

Using 8 mm diameter bar having Area of one bar (ast) = $\frac{\pi}{4} \times 8^2 = 50.24 \text{ mm}^2$ ½ M

(Note: Students may assume different bar dia.)

$$\text{Spacing } (S_x) = \frac{ast}{Ast} \times 1000 < 3d \text{ or } 300\text{mm whichever is less}$$

$$= \frac{50.24}{487.04} \times 1000 < (3 \times 145) \text{ or } 300 \text{ mm}$$ ½ M

$$= 103.15 \text{ mm} < 300 \text{ mm} \quad \text{Hence O.K}$$

$$= 100 \text{ mm (Say)}$$

Provide 8 mm diameter bar at 100 mm C/C along short span, Alternate bars bent up

Step 8) Dsitribution steel :-

(Note: Students may assume different bar dia.)

Using 6 mm bar Diameter having Area of one bar (ast) = $\frac{\pi}{4} \times 6^2 = 28.26 \text{ mm}^2$

$$Ast_{min} = \frac{0.15}{100} \times b \times D = \frac{0.15}{100} \times 1000 \times 165 = 247.5 \text{ mm}^2$$ ½ M

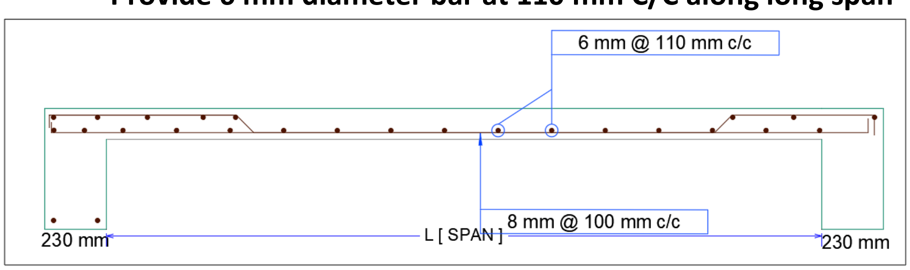
$$\text{Spacing } (S_y) = \frac{ast}{Ast} \times 1000 < 5d \text{ or } 450\text{mm whichever is less}$$

$$= \frac{28.26}{247.5} \times 1000 < (5 \times 135) \text{ or } 450 \text{ mm}$$ ½ M

$$= 114.18 < 450 \text{ mm} \quad \text{Hence O.K}$$

$$= 110 \text{ mm (Say)}$$

Provide 6 mm diameter bar at 110 mm C/C along long span



½ M

	(b)	**Calculate the reinforcement required for a RC slab panel of 6.3 m x 4.5 m is simply supported on all four sides. It has to carry the live load of 4 kN/m^2 including self-weight of slab. Use M25 concrete and Fe415 steel. Sketch the cross section of slab along longer span only showing reinforcement details. Use Modification factor equal to 1.4 and bending moment coefficient are αx = 0.085 and αy = 0.056.**	**6 M**

Given data: - Lx = 4.5 m , Ly = 6.3 m , Fck = 25 Mpa, Fy = 415 Mpa ,

LL = 4KN/m^2, αx = 0.085 & αy = 0.056.

Assume FF = 1KN/m^2 , M.F = 1.4

Step 1) Span and Aspect ration

Lx = 4.5 and Ly = 6.3

Aspect ratio = $\frac{Ly}{Lx} = \frac{6.3.}{4.5}$ =1.4 ≤ 2 , Slab is two way — ½ M

Step 2) Trial Depth

l_x more than 3.5 m and live load more than 3 KN/m^2

$\frac{l_x}{d}$ = 20 x M.F --------- same as per one way slab

$d_{provided} = \frac{Lx}{20 \text{ x M.F}} = \frac{4500}{20 \text{ x } 1.4}$ = 160.71 mm = 165 mm (Say)

Assume d' = 20 mm **(Note: Students may assume different cover)** — ½ M

D = 165 + 20 = 185 mm

Step 3) Revise Effective Span

Effective Span (l_x) = Minimum of i) Lcx + d — ½ M

= Minimum of i) 4.5 + 0.165 = 4.665 m

Step 4) Load calculation

Consider 1 m (b= 1 m or 1000 mm) wide strip of slab

a) Floor Finish FF = FF x 1 = 1 x 1 = 1 KN/m

b) Live Load (LL) = LL x 1 = 4 x1 = 4 KN/m

Total Working Load (W) = 5.0 KN/m — ½ M

Total Ultimate Load (Wu) = 1.5 W =1.5 x 5.0 = 7.5 KN/m

Step 5) Design Moment (Mu)

Mux = $\propto_x$ Wu $l_x{}^2$ = $0.085 \, X \, 7.5 \, X \, 4.665^2$ = 13.873 KN.m — ½ M

Muy = $\propto_y$ Wu $l_x{}^2$ = $0.056 \, X \, 7.5 \, X \, 4.665^2$ = 9.14 KN.m

Step 6) Check for Concrete depth

$$d_{req} = \sqrt{\frac{Mu \, max}{0.138 \, Fck \, b}}$$ ------------- for Fe 415

$$d_{req} = \sqrt{\frac{13.873 \text{ x } 10^6}{0.138 \, x \, 25 \, x \, 1000}}$$ — ½ M

d_{req} = 63.41 < $d_{Provided}$ Hence O.K

Step 7) Main steel :-

a) Reinforcement along short span

$$Astx = \frac{0.5\,Fck\ b\ do}{Fy}\left[1 - \sqrt{1 - \frac{4.6\,Mux}{Fck\ bdo^2}}\right] > Astmin\text{-----Hence O.K}$$ ½ M

$$Astx = \frac{0.5\ x\ 25\ x\ 1000\ x\ 165}{415}\left[1 - \sqrt{1 - \frac{4.6\ x\ 13.873\ x\ 10^6}{25\ x\ 1000\ x\ 165^2}}\right]$$

$= 238.72\ mm^2$

$Ast_{min} = \frac{0.12}{100}\ x\ b\ x\ D = \frac{0.12}{100}\ x\ 1000\ x\ 185 = 222\ mm^2$ ½ M

Astx > Astmin Hence O.k

Using 8 mm diameter bar having Area of one bar (ast) = $\frac{\pi}{4}\ x\ 8^2 = 50.24\ mm^2$

Note: Students may assume different bar dia.)

Spacing (S_x) = $\frac{ast}{Ast}$ x 1000 < 3d or 300mm whichever is less ½ M

= $\frac{50.24}{238.72}$ x 1000 < 3d or 300 mm

= 210.45 mm < 300 mm Hence O.K

= 210 mm (Say)

Provide 8 mm dia. @ 210 mm c/c along Shorter span. ult. Bent up

Step 8) Dsitribution steel :-

b) Reinforcement along Long span ½ M

$di = do- \emptyset x = 165-8 = 157\ mm$

$$Asty = \frac{0.5\,Fck\ b\ di}{Fy}\left[1 - \sqrt{1 - \frac{4.6\,Mux}{Fck\ bdi^2}}\right] > Astmin\text{-----Hence O.K}$$

$$Asty = \frac{0.5\ x\ 25\ x\ 1000\ x\ 157}{415}\left[1 - \sqrt{1 - \frac{4.6\ x\ 9.14\ x\ 10^6}{25\ x\ 1000\ x\ 157^2}}\right]$$

$= 164.172\ mm^2$

Asty < Ast_{min} Hence provide Asty = Ast_{min} = 222 mm^2

Using 8 mm diameter bar having Area of one bar (ast) = $\frac{\pi}{4}\ x\ 8^2 = 50.24\ mm^2$

(Note: Students may assume different bar dia.)

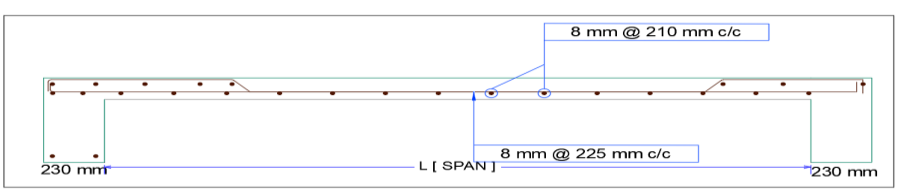
Spacing (S_y) = $\frac{ast}{Ast}$ x 1000 < 3d or 300mm whichever is less ½ M

= $\frac{50.24}{222}$ x 1000 < 3d or 300 mm

= 226.30 mm < 300 mm Hence O.K

= 225 mm (Say)

Provide 8 mm dia. @ 225 mm c/c along longer span. ult. Bent up



½ M

	(c)	**Design a cantilever slab 2 m x 3 m effective in plan dimensions is fixed along 3 m slab edge. It is loaded by superimposed load of 4 kN/m²including its own weight of slab. Use modification factor as 1.4 and take M20 concrete mix and Fe415 steel. Sketch the cross section of the slab showing reinforcement details. No Checks are required during design.**	**6M**

Given data: - Lx = 2m, M.F = 1.4, Fck =20 Mpa, Fy =415 Mpa,
LL + FF = 4 kN/m^2

Step 1) Span

Lx = 2 m ------------------------ Given

Step 2) Trial Depth

$d_{provided} = \frac{Lx}{7 \text{ x M.F}} = \frac{2000}{7 \text{ x } 1.4} = 204.08$ mm — ½ M

= 210 mm (Say)

Assume d' = 20 mm **(Note: Students may assume different cover)**

Overall (D) = d + d' = 210 + 20 = 230 mm — ½ M

Step 3) Revise Effective Span — ½ M

Effective Span (l_x) = Lc + $\frac{d}{2}$ = 2000 + $\frac{210}{2}$ = 2105 mm = 2.105 m

Step 4) Load calculation

Consider 1 m wide strip of slab (b= 1 m or 1000 mm)m

Slf wt + LL+ FF = 4 x 1 = 4 KN/m

Total Working Load (W) = 4.0 KN/m — ½ M

Total Ultimate Load (Wu) = 1.5 x 4 = 6.0 KN /m

Step 5) Design Moment (Mu)

$Mu = \frac{Wu\, l^2}{2}$

$= \frac{6.0 \text{ x } 2.105^2}{2}$ = 13.29 KN.m — ½ M

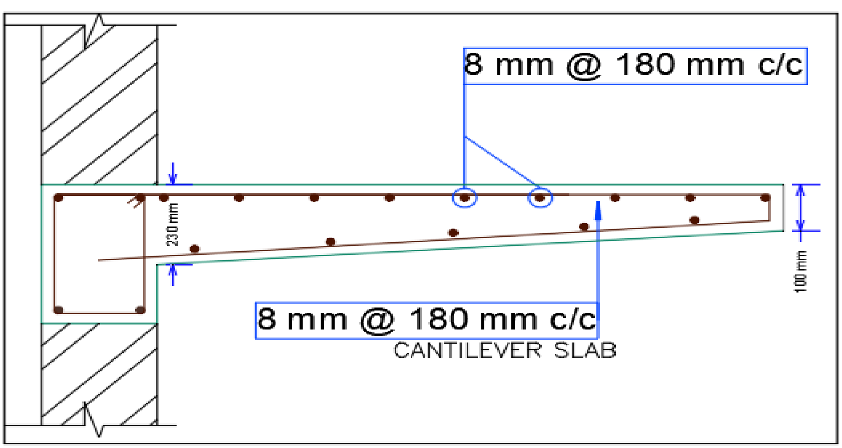
= 13.29 x 10^6 N.mm

Step 6) Check for Concrete depth

$d_{req} = \sqrt{\frac{Mu}{0.138\, Fck\, b}}$ ------------- for Fe 415

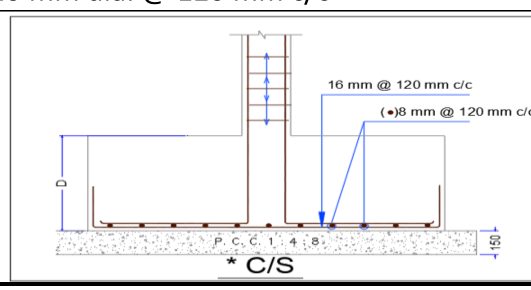
$= \sqrt{\frac{13.29 \text{ x } 10^6}{0.138\, x\, 20\, x\, 1000}}$ — ½ M

d_{req} = 69.39 mm < $d_{Provided}$ Hence O.K

		Step 7) Main steel :- Reinforcement along short span $Ast = \frac{0.5\,Fck\,b\,d}{Fy}\left[1 - \sqrt{1 - \frac{4.6\,Mu}{Fck\,bd^2}}\right]$ $Ast = \frac{0.5 \times 20 \times 1000 \times 210}{415}\left[1 - \sqrt{1 - \frac{4.6 \times 13.29 \times 10^6}{20 \times 1000 \times 210^2}}\right]$ $= 178.52\ mm^2$ $Ast_{min} = \frac{0.12}{100} \times b \times D = \frac{0.12}{100} \times 1000 \times 230 = 276\ mm^2$ $Ast < Ast_{min}$ Hence provide $Asty = Ast_{min} = 276\ mm^2$ Using 8 mm diameter bar having Area of one bar (ast) = $\frac{\pi}{4} \times 8^2 = 50.24\ mm^2$ **(Note: Students may assume different bar dia.)** Spacing (S_x) = $\frac{ast}{Ast} \times 1000$ < 3d or 300mm whichever is less $= \frac{50.24}{276} \times 1000$ < 3d or 300 mm = 182.02 mm < 300 mm Hence O.K = 180 mm (Say) **Provide 8 mm diameter bar at 180 mm C/C along short span** **Step 8) Dsitribution steel :-** $Ast_{min} = \frac{0.12}{100} \times b \times D = \frac{0.12}{100} \times 1000 \times 230 = 276\ mm^2$ Using 8 mm bar Diameter having Area of one bar (ast) = $\frac{\pi}{4} \times 8^2 = 50.24\ mm^2$ **(Note: Students may assume different bar dia.)** Spacing (S_y) = $\frac{ast}{Ast} \times 1000$ < 3d or 300mm whichever is less $= \frac{50.24}{276} \times 1000$ < 35 or 450 mm = 182.02 mm < 300 mm Hence O.K = 180 mm (Say) **Provide 8 mm diameter bar at 180 mm C/C along long span**  	½ M ½ M ½ M ½ M 1 M

Q. No.	Sub Q.N.	Answers	Marking Scheme
Q-6		**Attempt any TWO of the following:**	**12**
	(a)	**A square column of RCC is carrying working load of 1600 kN. The length of unsupported column is 3 m and is effectively held in position at both ends but restrained against rotation at one end only. Design the axially loaded short column using M25 and Fe 415 as construction.**	**6 M**
		le = 3 m, P = 1600 kN, M-25, Fe-415. Asc = 1% of Ag= 0.01Ag mm^2 Ac = Ag – Asc Ac = Ag - 0.01 Ag = 0.99Ag	1M
		Factored Load = Pu = P x 1.5 = 1600 x 1.5 = 2400 kN. Pu = (0.4 x fck x Ac) + (0.67 x fy x Asc) 2400 x 10^3 = [(0.4 x 25 x 0.99Ag) + (0.67 x 415 x 0.01Ag)] = 9.9Ag + 2.78Ag = 12.68Ag Ag = (2400x 1000)/12.68 = 189266.98 mm^2	1M
		Size of Column = sqrt(189266.98) = 435.04 mm Say 440 mm Therefore provide 440 mm x 440 mm Ag provided = 193600 mm^2 Ac = 0.99 x 193600 = 191664.00 mm^2 Asc = 0.01 x 193600 = 1936 mm^2	1M
		Provide 16 mm dia. 10 bars. **(Note: Students may provide different combination of no.and dia. of bars.)** Lateral Ties: Diameter of bar: (Greater of below) i. ¼ of main bar dia. = 16/4 = 4 mm ii. 6 mm. Provide 6 mm dia. bars.	1M
		Pitch: (Least of below) i. 16 times dia. Of main bar = 16 x 16 = 256 mm. ii. Least lateral dim. = 440 mm. iii. 300 mm. Provide pitch 250 mm. Hence provide 6 mm dia. @ 250 mm c/c.	1M
		Check for Minimum eccentricity emin = L/500 + D/30 or 20 mm whichever is grater emin = 3000/500 + 440/30 = 20.66 or 20 mm emin < 0.05 D emin < 0.05 x 440 =22 20.66 < 22 Hence O.K.	1M

	(b)	**Determine the reinforcement for an isolated square footing with uniform depth is supported over soil strata having safe bearing capacity as 190 kN/m². The square column of 400 mm x 400 mm in section which transmits an axial load of 1000 kN through RC footing. Use M20 concrete mix and Fe 415 steel grade. No checks for one way action and punching shear applied for footing depth calculation. Also draw the cross section of footing showing the reinforcement details.**	**6M**

Safe bearing capacity	190 N/m^2	
Working Load =P	1000 kN	1M
Self-weight of footing = 10% of load on column.	100 kN	
Total ultimate load on soil	1100 kN	
Area of footing required = Total ultimate load on soil / Ultimate bearing capacityof soil	1100/190 = 5.78 m^2	1M
Size = SQRT(Area)	2.45 m	
Provide size	2.45 m x 2.45 m	
Actual area provided	6.00 m^2	
Net ultimate upward pressure (qnu) = Ultimateload on column / Actual area provided	1000 / 6.00 = 166.67 kN/m^2	
Projection (a)	(2.45 – 0.40) / 2 = 1.025 m	
Mu = qnu x a^2 / 2	87.55 kN.m	
d required = SQRT(Mu / 0.138 x fck x b)	SQRT(87.55 x 10^6 / 0.138 x 20 x 1000) = 178.10 mm	1M
Overall depth D = d + cover 60 mm	240 mm	
Provide	D = 240 mm & d = 180 mm	
Ast = 0.5 x fck x b x d {1 – SQRT[1 – (4.6 x Mu) / (fck x b x d^2)]} / fy	0.5 x 20 x 1000 x 180 {1 – SQRT[1 – (4.6 x 87.55 x 10^6) / (20 x 1000 x 180^2)]} / 415 = 1668.89 mm^2	1M
Spacing for 16 mm dia. Bars = 1000 x A1 / Ast	120.47 mm	1M
Provided	16 mm dia. @ 120 mm c/c	
		1M

	(c)	***i) Calculate the ultimate load carrying capacity of RC column having 400 mm x 400 mm in section. It is reinforced with longitudinal steel by 8- bars of 12 mm diameter. Use M 20 concrete mix and Fe 415 steel grade.***	**6M**

Size of Column 400 mm x 400 mm M-20, Fe-415.

Asc = 8 x π/4 12^2 =904.78 mm^2 of Ag= 400 x 400 = 160000 mm^2 Ac = 160000-904.78 = 159095.22 mm^2 — 1M

To Find :- Pu = ?. — 1M

Pu = (0.4 x fck x Ac) + (0.67 x fy x Asc)

Pu = [(0.4 x 20 x Ac) + (0.67 x 415 x Asc)]

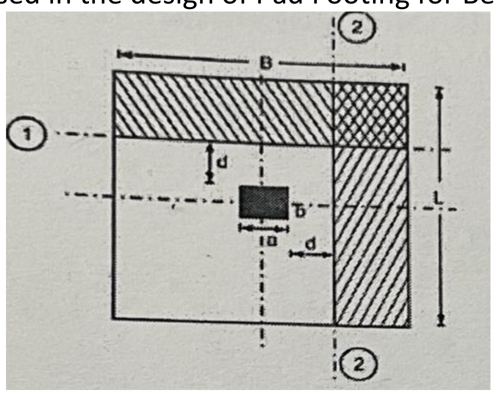
= (0.4 x 20 x 159095.22) + (0.67 x 415 x 904.78)

= 1524335.84 N — 1M

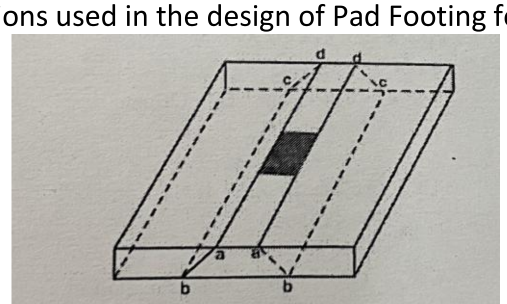
= 1524.34 kN.

i) Sketch the critical sections and their respective locations used as recommended by IS-456-2000 code while designing depth of Pad footing for bending and shears only.

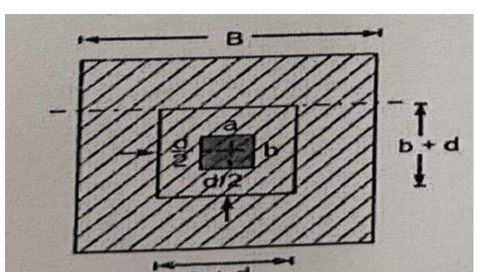
i) Critical Sections used in the design of Pad Footing for Bending — 1M



ii) Critical Sections used in the design of Pad Footing for Shears — 1M



One-way Shear Failure of Column Footing



Two–way Action — 1M