85

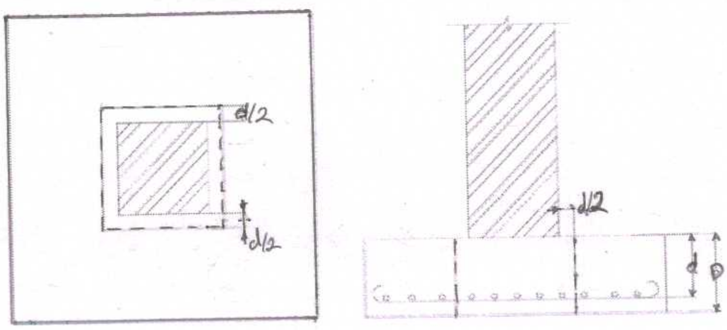
April
page No. 18

STRUCTURAL DESIGN-I

TED(15)-5015

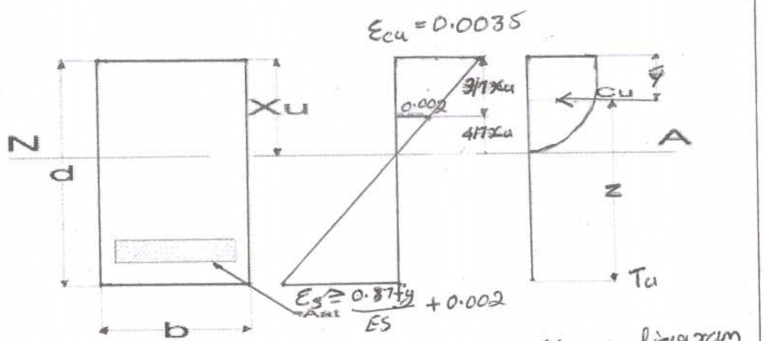
SCHEME OF VALUATION

Qstn. No.		Scoring Indicators	Split up Score	Sub Total	Total
		PART			
I	1	Water cement ratio is the ratio of weight (vol.) of water added is the weight (vol.) of cement. More, the W/C ratio workability increases while, the strength decreases. Less the W/C ratio, workability decreases and the strength increases		2	
	2	'Characteristics load ' means the value of load which has a 95% probability of not being exceeded during the life of the structure 'Characteristics strength' means that value of strength of the material below which not more than 5% of the test results are expected to fall		2	
	3	1. Main bar available at support 2. Vertical stirrups 3. Inclined stirrups 4. Bent up bars		2	
	4	On two way slabs , tension reinforcement shall be provided at any corner where the slab is simply supported on both edges , meeting at that corner. it shall be in four layers and length should not be less than 1/5 of shorter span. Area of such reinforcement shall not be less than 75% of Ast in each layer, subjected to a maximum spacing of 3d or 300 mm where d is the effective death of slab.		2	
	5	The shear effected on column footing around the column at a distance of d/2, due to imposed load on the column ,which is also known as Two way shear. Were d is the effective death of footing.		2	10

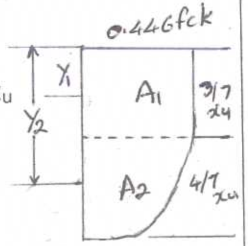


PART-B

II 1 Lever arm is the distance between the centroid of the compressive force and the centroid of the tensile force. 6



Beam strain diagram Stress diagram



Position of centroid of Stress Block

Area of rectangular portion$A_1 = 0.446fck \times \frac{3}{7} x_u$

$= 0.1911fck\ x_u$

Distance of centroid from top,$Y_1 = \frac{1}{2} \times \frac{3}{7}$

$= 0.2143x_u$

Area of parabolic portion $A_2 = \frac{2}{3} \times 0.446fck \times \frac{4}{7} x_u$

$= 0.1699fck x_u$

Distance of centroid from top, $Y_2 = \frac{3}{7} x_u + \frac{4}{7} x_u \times \frac{3}{8} = 0.6429x_u$

Total area $A_1 + A_2 = 0.1911fck\ xu + 0.1699fck\ x_u$

$= 0.361fck\ x_u$

∴ Distance of centroid from top,

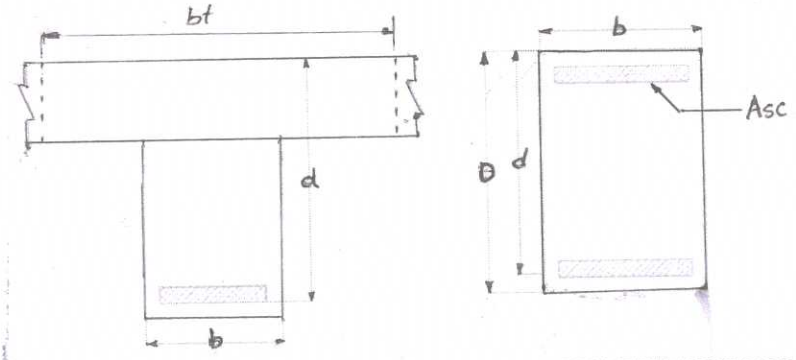
$y = x_u[\frac{0.1911 \times 0.2143 + 0.1699 \times 0.6429}{0.361}] = 0.416\ x_u$

Where x_u = depth of NA = $\frac{0.87fyAst}{0.36fckb}$

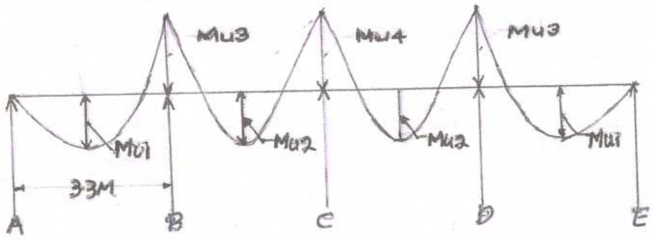
∴ Lever arm $Z = d - y = d - 0.416\ x_u$

$= d - = \frac{0.416 \times 0.87fyAst}{0.36fckb}$

$Z = d - = \frac{fyAst}{fckb}$

	2	 T BEAM DOUBLY REINFORCED BEAM A beam that provided steel on compression side as well as on tension side to carry an axes load due to restriction of there size(especially over all death) or tension effect is called doubly reinforced beam. A beam cast monolithically with the slab is called T –beam. A T-beam may be doubly or singly weather it is provided compression reinforcement or not. Doubly reinforced beam , steel should be provided no compression side for an amount of BM , more than BM of balanced X^n.an amount of steel curresponding to compression steel shall we provided at bottom in addition to the steel required for balanced X^{n}. For T-beam the main reinforcement of flange(slab) shall be provided transverse to the beam. If not so , 60% of the main bar in slab should be provided in transverse direction of the beam to the slab.		6	
	3	1. Calculate the axial load ‘P’ over the column and then factored load Pu 2. Determine grade of steel and concrete. 3. Assume the percentage of longitudinal reinforcement ‘P’ between 0.8 % and 4% and substituted in the equation. P_U=0.4fck Ac+0.67fy Asc Ie,p_u=0.4fck $(Ag - \frac{p}{100}Ag) + 0.67fy\frac{p}{100}Ag$ And find cross area of column Ag Note: If helical reinforcement is used as lateral ties ,P_u shall be devided by 1.05 4. Determine the size of column a) If square column, side a=$\sqrt{Ag}$ b) If circular, diameter D=$\frac{\sqrt{4Ag}}{\pi}$ c) If rectangular, depth to width ratio and determine the size if a=2b Area $a \times b =$ $2b^2$=Ag		6	

		$\therefore b = \frac{\sqrt{Ag}}{2}$ 5. Calculate the area of reinforcement=$\frac{P}{100}$Ag Assuming the diameter of bar, Calculate the number of longitudinal reinforcement and select the number of size of bars as per IS456:2000.			
	4	The effective span of stair with out stringer beams shall be taken as the following horizontal distance a) If top and bottom risers are supported on beams spanning parallel with the risers, the c/c distance of beams. b) If top and bottom risers supported to the edge of a landing slab which span parallel to the risers, a distance equal to the going of stair plus half the width of landing or 1m. Which ever is less at each end. c) If the landing spans the same direction of the flight slab they shall be considered as a single slab at the span is the c/c distance of supporting beams or walls measured horizontally.		6	
	5	<u>According to Size</u> If the ratio of long span to short span is less than 2, they are considered as two way slab. If greater than 2, they are one way slab. Ie, if $\frac{ly}{lx} \leq 2$, two way slab If $\frac{ly}{lx} > 2$,one way slab According to supporting conditions, A) Simply supported slab : If the slabs are provided to a single room and supported simply over the support. B) Continuous slab : If the slab cast monolithically (continuously) for several rooms, C) Fixed slab :If the slabs cast monolithically with the supporting beam or if the edges are prevented from uplifting by providing loads on the edges, such as walls etc.		6	
	6	1. To reduce the quantity of steel and hence to reduce the cast of construction. 2. To avoid unnecessary conjunction of steel bars in a section and hence to increase work ability. The main criteria to determine the amount of curtailment is the bending moment and shear force at that section		6	

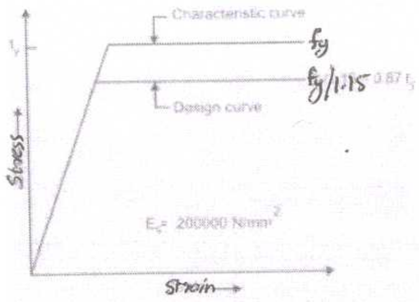


	7	Effective span L=303m Wd=5KN/m^2 Wud=1.5×5 = 7.5 KN/m^2 Wl=2 KN/m^2 Wul=2×1.5=3 KN/m^2 Mid span moment at end spans AB & DE $M_{u1} = \frac{WudLL^2}{12} + \frac{WulL^2}{10} = \frac{7.5\times3.3^2}{12} + \frac{3\times3.3^2}{10}$ =10.08 kNm Mid span moment at interior spans BC & CD $M_{u2} = \frac{WudLL^2}{16} + \frac{WulL^2}{12} = \frac{7.5\times3.3^2}{16} + \frac{3\times3.3^2}{12}$ = 7.82kNm Moment at supports A&E = 0 Moment at support next to end support, at B&D $M_{u3} = -[\frac{WudLL^2}{10} + \frac{WulL^2}{9}] = -[\frac{7.5\times3.3^2}{10} + \frac{3\times3.3^2}{9}]$ = (-)11.80kNm Moment at interior support C $M_{u3} = -[\frac{WudLL^2}{12} + \frac{WulL^2}{9}] = -[\frac{7.5\times3.3^2}{12} + \frac{3\times3.3^2}{9}]$ = (-)10.44kNm		6	30

Part C

UNIT I

III A (6 marks)



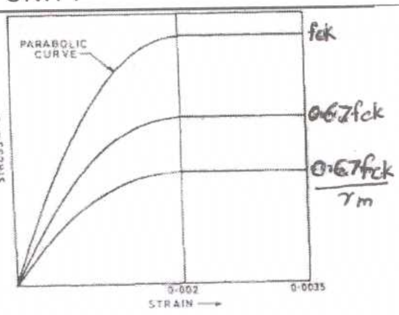


FIG. 21 STRESS-STRAIN CURVE FOR CONCRETE

The stress-strain relationship considered for concrete is the compressive strength of concrete cube for particular grade of concrete. In this diagram curve 1 represents the average compressive strength of concrete cubes, fck. Curve 2 represents the safe compressive strength and curve 3 represents the safe compressive strength considered for limit state method of design, applying a partial safety factor γm to the safe compressive strength. All the three curves shows increase in stress corresponding to the strain upto a stress of 0.002 (proof stress) in parabolic and then after increase in stress is zero corresponding to the increase in strain.

Stress-Strain diagram of steel represent the tensile strength of steel in stress corresponding to the strain developed. Upto the yield point the stress-strain ratio remain constant (diagram shows a straight line) and then after parabolic to a certain extend. Ultimate tensile strength(characteristic) of steel f_y is considered for design and a partial safety factor 1.15 is applied in limit state method of design.

B (9 marks; total 15)

Given:

Applied BM = 50kNm

Grade of concrete =M20

Grade of steel = Feu15

B=250mm

Solution:

Factored BM $M_U = 1.5\times50 = 75$kNm

$M_U=M_{Ulimt} = 0.36fck\frac{Xu\,max}{d}[1-0.42\frac{Xu\,max}{d}]bd^2$

$75\times 10^6 = 0.36\times20\times0.48(1-0.42\times0.48)250d^2$

$\therefore$ effective depth, = 330mm

Providing effective cover dc = 40mm,

Over all depth D = 330+40 = 370

Area of steel Ast = $\frac{Mu}{0.87fy(d-0.42Xumax)}$

$$= \frac{75\times10^6}{0.8\times415(330-0.420.48\times330}$$

$$= 789mm^2$$

Assuming 16mmϕ bar,

No. of bars $= \frac{789}{201} = 3.9$

Check for spacing, Sv = $\frac{250-2\times25-4\times16}{4-1}$

$= 45mm > 25mm$

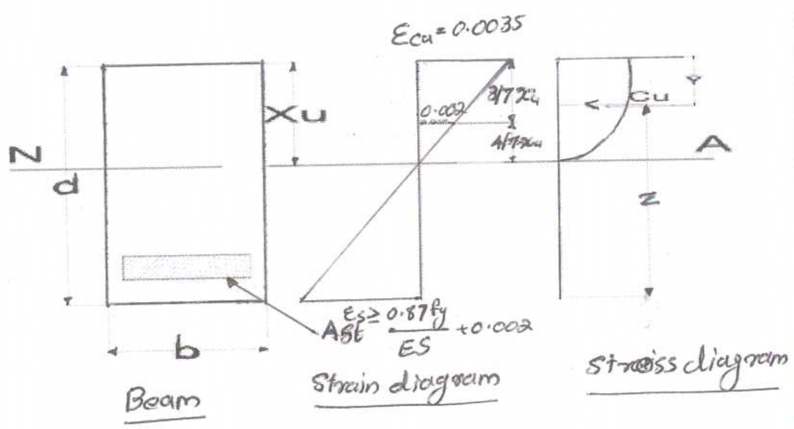
Hence provide 16mmϕ bar 4 Nos as tension reinforcement

<u>Result:</u>

Size of beam = 250×370mm

Tension reinforcement = 16mmϕ bar 4 Nos

IV A — 6



The natural axis of flexural member is the imaginary plane along or parallel to the axis of the member. The area above NA is subjected to compressive force and that below is tensile force.

Let $r\mu$ = The depth of neutral axis from the top

Strain in concrete and steel varies from 0 to 0.0035 towards the top and 0 to $\frac{0.87fy}{ES}$+0.002 towards bottom from NA. Distance of the fibre from NA where the strain 0.002 is equal to

$x_u \times \frac{0.002}{0.0035} = \frac{4}{7} x_u$ and the distance above it upto top $= \frac{3}{7} x_u$.

<u>Area of stress block :</u> The stress block is seen to be a rectangle at the top upto a depth of $\frac{3}{7} x_u$ and remaining depth of $\frac{4}{7} x_u$ shows parabolic

∴ Total compressive force above NA,

$$Cu = b\times\frac{3}{7}x_u\times 0.446fck + b\times\frac{3}{7}x_u\times\frac{2}{3}\times 0.446fck$$

$$= 0.36\, fck x_u b$$

		Similarly total tensile force, Tu = 0.87fyAst [Tensile strength in concrete is negligible] For equilibrium, equate Tu = Cu Ie 0.87 fyAst = 0.36 fckxb $\therefore \quad x_u = \frac{0.87\text{fyAst}}{0.36\text{fckxb}}$ Limiting value of NA $x_{u\,max} = \frac{\varepsilon Cu}{\varepsilon Cu+\varepsilon Su} \times d$ $\therefore \quad \frac{xu\ max}{d} = \frac{0.0035}{0.0035+0.002+\frac{0.87fy}{ES}} = \frac{700}{1100+0.87fy}$			
	B	Given: Effective span, l = 5m Width, b = 300mm Effective depth , d = 550mm Ast = 2500mm^2, Asc = 982mm^2, fy= 415MPa, dc = 50mm Solution: For Fe 415 steel, $\frac{xu\ max}{d}$= 0.48 $\therefore$ $x_{u\,max}$ = 0.48×550 = 264mm Assuming fsc = fst = 0.87fy, equating compressive force to tensile force $C_{Cu}+C_{Su}$=Tu C_{Cu}=0.36fckx_ub = 0.36×20×x_u×300 = 2160 x_uN C_{Su}=(0.87fy-0.446fck)Asc = (0.87×415-0.446× 20)982 =345791N Tu = 0.87fyAst = 0.87×415×2500 = 902625N $\therefore$ 2160 x_u+345791 = 902625 $\therefore$ x_u =258mm< $x_{u\,max}$ UR section $\therefore$ Mu = CCu(d-0.416x_u)+C_{Su}(d-dc) = 2160×258(550-0.416×258)+345791(550-50) = 419.59kNm Applied BM M = $\frac{Mu}{1.5}$ =279.72 kNm Max UD load W = $\frac{8M}{l^2} = \frac{8\times279.72\times10^6}{(5\times10^3)^2}$ = 89.5kN/m		9	15
UNIT II					
V	A	Given : Width of beam b = 250mm Effective depth d = 330mm Ud load w = 25kN/m		6	

	Effective span $l = 4m$ $Ast = 16mm\phi$ 4 Nos Grade of steel $fy = 415$ MPa Grade of concrete $fck = 20MPa$ <u>Solution :</u> Shear force $V = \frac{wl^2}{2} = \frac{25\times4^2}{2} = 50kN$ $Vu = 1.5V = 75kN^2$ Shear stress $\tau_v = \frac{Vu}{bd} = \frac{75\times10^3}{250\times330} = 0.91N/mm^2$ % of steel at support = $\frac{100As}{bd} = \frac{100\times201\times4}{250\times330} = 0.97$ Permissible shear stress $\tau_c = 0.56+\frac{0.06\times0.22}{0.25} = 0.61N/mm^2$ $\tau_v > \tau_c$ $\therefore$ Shear reinforcement shall be designed. Providing $8mm\phi$ bar 2 legged stirrups, Spacing $Sv = \frac{0.87fyAsvd}{Vus}$ $= \frac{0.87\times415\times2\times50\times330}{(0.91-0.61)250\times330} = 481mm$ Max. spacing shall be limited to 0.75d or 300mm which ever is less. $0.75d = 0.75\times330 = 247mm$ Hence provided $8mm\phi$ 2 legged stirrups at 240mm c/c.			
B	<u>Given :</u> $Bf = 740mm$, $bw = 240mm$, $d = 350mm$, $Df = 85mm$, $M = 80kNm$, $fy = 415MPa$, $fck = 20MPa$ <u>Solution :</u> Design moment $M_{uD} = 1.5\times80 = 120kNm$ Assuming $x_u = Df$, $Mu_1 = 0.36fck.bf.Df(d-0.416\ Df)$ $= 0.36\times20\times740\times85(350-0.416\times85)$ $= 142.5kNm$ $Mu_1 > Mu_D$ $\therefore$ $Mu_D = 0.87fy\ Ast\ d(1-\frac{fy\ Ast}{fck\ bf.d})$ $120\times10^6 = 0.87\times415\ Ast\times350(1-\frac{415\ Ast}{20\times740\times350})$ Ie $Ast^2 - 12500Ast+11870140 = 0$ From which $Ast = 1035mm^2$ Providing $22mm\phi$ bar, No. of bars = $\frac{1035}{\pi\times\frac{22^2}{4}} = 2.72$		9	15

		Providing 22mmϕ bar = 3 Nos Check for spacing $S = \frac{240-2\times25-3\times22}{2} = 62mm > 25mm$ Hence Providing 22mmϕ bar 3 Nos			
VI	A	1. As per the longitudinal reinforcement available at support, a limited quantity of shear stress τ_c, will be resisted by such reinforcement. If actual shear stress $\tau_v < \tau_c$ that allowed in IS456-2000, no shear reinforcement shall be designed. Nominal shear reinforcement shall be provided to a maximum spacing 0.75d or 300mm which ever is less. 2. If $\tau_v > \tau_c$, shear reinforcement shall be designed for a SF of Vus = Vu- $\tau_c$bd 3. Shear reinforcement shall be designed as 1. Vertical or inclined stirrups 2. Bent up bars along with stirrups 4. For vertical stirrups, $Vus = \frac{0.87fyAsvd}{Sv}$ For inclined stirrups $Vus = \frac{0.87fyAsvd\sin\alpha}{Sv}$ Assuming ϕ of bars, spacing Sv can be calculated. The spacing thus obtained shall be limited to 0.75d or 300mm taking least. 5. If bent up bars provided, half of Vus or capacity to resist SF by bent up bars provided, taking least shall be accounted for it ie, $Vus_1 \leq \frac{1}{2}Vus$. Remaining SF subject to a minimum 50% of Vus shall be accounted for the design of stirrups Ie, $Vus_2 = Vus - Vus_1$		6	
	B	Given : Bf = 800mm, bw = 250mm, Df = 100mm, w = 25kN/m, l= 8m, fy = 415MPa, fck = 20MPa Solution : Assume 500mm effective depth for the beam Ie d = 500mm Assuming x_u = Df, $Mu_1 = 0.36fck.bf.Df(d-0.416\ Df)$ $= 0.36\times20\times800\times100(500-0.416\times100)$ $= 321.63kNm$ Factored BM due to load		9	15

		$Mu_D = \frac{Wul^2}{8} = \frac{25\times1.5\times8^2}{8}$ = 300kNm $\therefore$ $Mu_D < Mu_1$ and nearest values, assumptions are correct Hence provided 500mm effective depth <u>Area of steel</u> $Mu_D = 0.87fy\ Ast\ d(1-\frac{fy\ Ast}{fck\ bf.d})$ $300\times 10^6 = 0.87\times415\ Ast\times500(1-\frac{415\ Ast}{20\times800\times500})$ $= \frac{19277.14\pm15603.42}{27}$ $= 1837mm^2$ Hence Provide area of steel = $1837mm^2$			
		<u>UNIT III</u>			
VII	A	1. Effective span, l = c/c distance of support Or Clear span + effective depth which is less. 2. <u>Control of deflection :</u> Ratio to effective depth ratio upto 10m span shall be less than or equal to 20 3. <u>Minimum and maximum reinforcement</u> Area of reinforcement $\nless$ 0.15% of total cross sectional area. $\nless$ 0.12% high strength or welded bars $\ngtr$ 0.04bD 4. <u>Max. diameter :</u> ϕ of bar shall not exceed $\frac{1}{8}$D of slab. 5. <u>Spacing of reinforcement:</u> Min. spacing$\nless$ a) diameter of larger bar b)5mm + nominal max. size of aggregate Max. spacing$\ngtr$ 3d or 300mm. for solid slabs For distribution bar, max spacing $\ngtr$ 0.2d or 450mm Which ever is spaller 6. <u>Cover to reinforcement :</u> Nominal cover to reinforcement shall be provided as per table 16 of IS I456:2000, subject to a minimum cover 20mm.		6	
	B	<u>Given :</u> size of room = 3.5m×10m Wall thickness = 200mm U D load w = $10kN/m^2$ Fck = 20MPa fy = 415 MPa Effective span l = 3.5+0.2 = 3.7 $Mu = \frac{Wul^2}{8} = \frac{10\times1.5\times3.7^2}{8} = 25.67$ kNm <u>Effective depth</u>		9	15

$$D_{reqd} = \sqrt{\frac{Mu}{0.36fck\frac{Xumax}{d}\left(1-\frac{0.416Xumax}{d}\right)b}}$$

$$= \sqrt{\frac{25.67\times10^{6}}{0.36\times20\times0.048(1-0.416\times0.48)1000}}$$

= 96.34mm

Hence provide 100mm effective depth

Area of steel

$$Ast = \frac{Mu}{0.87fyd(1-\frac{0.416Xumax}{d})}$$

$$= \frac{25.67\times10^{6}}{0.87\times415\times100(1-0.416\times0.48)}$$

= 888mm^2

Assuming 8mmϕ of bar,

$$\text{Spacing} \quad S = \frac{A\phi b}{Ast} = \frac{50\times1000}{888}$$

= 56mm

Min. spacing = 25mm.

Hence provide 8mmϕ bar 55mm c/c

VIII | A | Given : Unsupported length of cantilever slab,l = 2m | 6

Depth of slab = 125mm

Imposed load = 3kN/m^2

Solution :

Weight of slab = 0.125× 25 = 3.125 kN/m^2

Total UD load = 3+3.125 = 6.125 kN/m^2

$$Mu = \frac{Wul^2}{2} = \frac{6.125\times1.5\times2^2}{2}\ 18.375\text{kNm}$$

Assuming 25mm effective cover,

Effective depth d = 125-25 = 100mm

$$Ast_{reqd} = \frac{Mu}{0.87fyd(1-\frac{0.416Xumax}{d})}$$

Assuming M_{20} concrete and Fe415 steel,

$$Ast = \frac{18.375\times10^{6}}{0.87\times415\times100(1-0.416\times0.48)}$$

= 636mm^2

Assuming 8mmϕ of bar,

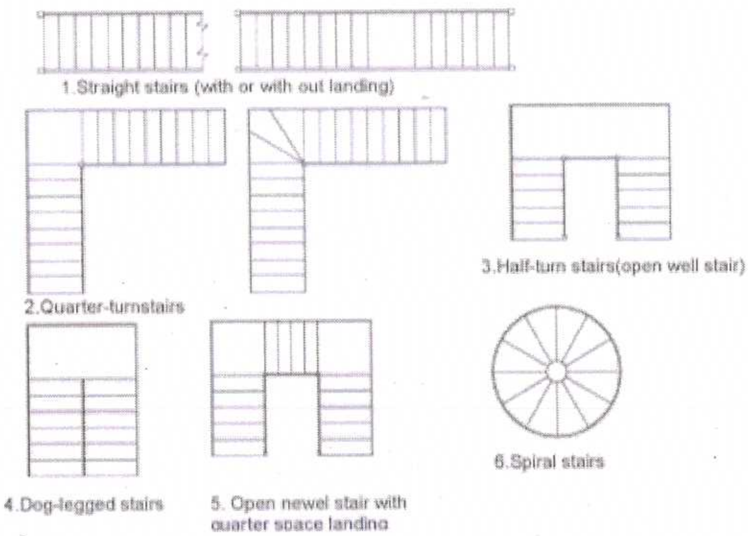
$$\text{Spacing} \quad S = \frac{A\phi b}{Ast} = \frac{50\times1000}{636}$$

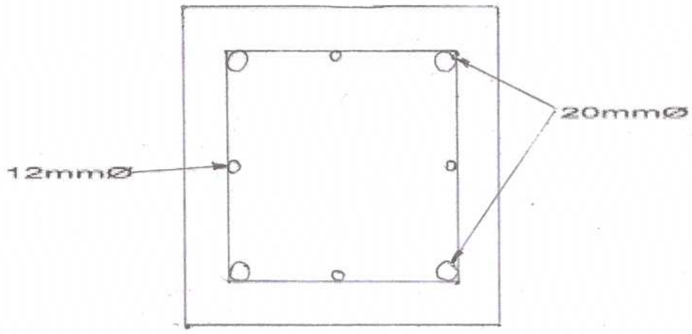
= 78mm

Min. spacing = 25mm.

Hence provide 8mmϕ bar@ 75mm c/c

	B	<u>Given :</u> size of room = 4m×5m, total load = 7.5 kN/m^2 Assume Fe415 grade steel and M20 concrete $\therefore \quad \frac{Xumax}{d} = 0.48$ Ru = 0.36fck $\frac{Xumax}{d}(1-\frac{0.416\,Xumax}{d})$ 0.36×20×0.48(1-0.416×0.48) = 2.766 Mux = $\alpha_x$wlx^2 and Muy = α_y wlx^2 Assuming 100mm effective depth, Effective span $lx = 4.1m$ and $ly = 5.1m$ $\frac{ly}{lx} = \frac{5.1}{4.1} = 1.244 < 2$ Hence two way slab. From table 26, $\alpha_x = 0.072 + \frac{0.005}{0.01} \times 0.04 = 0.074$ $\alpha_y = 0.056$ $\therefore \; Mux = 0.074 \times 7.5 \times 1.5 \times 4.1^2 = 13.994$kNm $Muy = 0.056 \times 7.5 \times 1.5 \times 4.1^2 = 10.59$kNm D$_{reqd}$ = $\sqrt{\frac{Mu}{Ru.b}} = \sqrt{\frac{13.994\times10^6}{2.766\times1000}} = 71$mm 71mm < 100mm Hence safe <u>Area of steel</u> Along shorter span = $\frac{Mux\ 13.994\times10^6}{0.87\times415\times100(1-0.416\times0.48)} = 483$mm^2 For 8mmϕ bar, Spacing S = $\frac{50\times1000}{483}$ = 103mm c/c Along longer span = $\frac{Muy\ 10.59\times10^6}{0.87\times415\times100(1-0.416\times0.48)} = 367$mm^2 For 8mmϕ bar, Spacing S = $\frac{50\times1000}{367}$ = 136mm c/c Width of middle strip Along $lx = \frac{3}{4} \times 5.1 = 3.83m$ Along $ly = \frac{3}{4} \times 4.1 = 3.1m$ Provide 8mmϕ bar @ 100mm c/c to a width of 3.83m on shorter span and 130mm c/c to a width of 3.1m on longer span at centres.		9	15
		<u>UNIT IV</u>			
IX	A	1. Straight stair (with or without landing) 2. Quarter turn stair 3. Half turn stair 4. Dog legged stair 5. Open newel stair with quarter space landing		6	

		6. Circular stair 7. Spiral stair 			
	B	<u>Given :</u> Axial load P = 1200kN Grade of steel = Fe415 Grade of concrete = M20 Assuming 1% of longitudinal reinforcement on column, (bw 0.8% &4%) $Pu = 0.4fck\ Ac + 0.67fyAsc$ $= 0.4fck(Ag - \frac{1}{100}Ag) + 0.67fy \times \frac{1}{100}Ag$ $1200 \times 1.5 \times 10^3 = 0.4 \times 20(Ag(1-0.01) + 0.67 \times 415 \times 0.01Ag$ $= Ag[7.92 + 2.781]$ $\therefore \quad Ag = \frac{1800 \times 10^3}{10.701} = 168208mm^2$ For square column, side = $\sqrt{Ag}$ = 410mm Hence provide 410mm square column. Area of steel = 0.01Ag = 0.01×168208 = $1682.1mm^2$ Taking 20mmϕ 4 Nos and 12mmϕ 4 Nos, Area provided = (314+113)4 = $1708mm^2 >$ reqd.		9	15



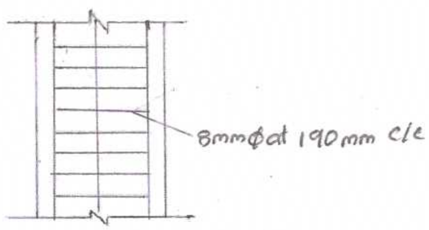
Lateral Ties

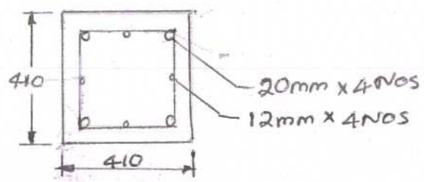
Taking 8mmϕ bar for lateral ties

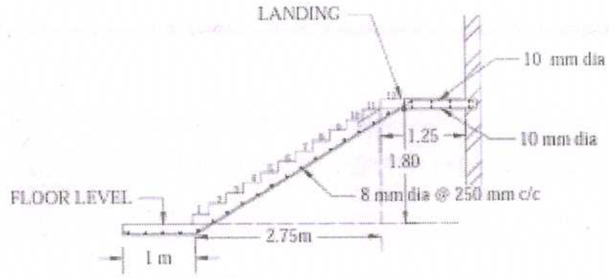
Pitch : least of

1. Least lateral dimension of column = 410mm
2. 16 times the smallest ϕ of reinforcement=16×12=192mm
3. 300mm

Hence provide 8mmϕ lateral ties at 190mm c/c





X	A	 		6	
	B	<u>Given :</u> Size of column = 400×400mm Axial load P = 600kN SBC of soil = 180kN/m^2 Grade of steel = Fe415 Grade of concrete = M25 Area of footing $= \frac{P}{SBC} = \frac{600}{180} = 3.33$ m^2 Size of footing = 1.83m Provide 2m×2m square footing Upward pressure of soil on footing, $q = \frac{P}{A\ provided}$ $= \frac{600\times10^3}{2000^2} = 0.15$N/mm^2 $q_u = 1.5\times0.15 = 0.225$N/mm^2 $Mu = \frac{qu\times B}{8}(B-b)^2 = \frac{0.225\times2000}{8}(2000-400)^2$ = 144kNm $D_{reqd} = \sqrt{\frac{Mu}{0.138fck.B}} = \sqrt{\frac{144\times10^6}{0.138\times25\times2000}}$ = 145mm In consideration of shear stresses the effective depth shall be increased. Hence provide 250mm effective depth Area of steel required $= \frac{Mu}{0.87fyd\left(1-\frac{0.416\ Xumax}{d}\right)}$ $= \frac{144\times10^6}{0.87\times415\times250(1-0.416\times0.48)}$ = 1994mm^2 Providing 12mmØ bar, Spacing $= \frac{113\times1000}{1994} = 56$mm Minimum spacing = 25mm Hence provide 50mm c/c		9	15

Ast provided = = $\frac{113\times1000}{50}$ = 2260mm^2

% of steel = $\frac{100As}{bd} = \frac{100\times2260}{1000\times250}$ = 0.9%

Check for one way shear

Critical X^n for one way shear is considered at a distance d from the face of column

Shear force Vu = $q_u \times B[(\frac{B-b}{2}) - d]$

= $0.225\times2000[(\frac{2000-400}{2}) - 250]$

= 247.5kN

Shear stress $\tau_v = \frac{Vu}{Bd} = \frac{247.5\times10^3}{2000\times250}$ = 0.495 N/mm^2

Permissible stress τ_c for M25 concrete

% of steel	τ_c
0.75	0.57
0.90	?
1.0	0.64

$\tau_c = 0.57 + \frac{0.64-0.57}{1.0-0.75} \times (0.90 - 0.75)$

= 0.612 N/mm^2

For solid slabs τ_c may be increased by k τ_c

= 1.1×0.612 = 0.673 N/mm^2

$\tau_v < k\,\tau_c$ hence safe

Check for two way shear

Critical X^n for two way shear shall be at a distance d/2 from the face of column around.

Vu = $q_u [B^2 - (b+d)^2]$

= $0.225[2000^2 - (400+250)^2]$

= 804.94kN

Shear stress due to punching

$\tau_v = \frac{Vu}{b_0 d}$

b_0 = 4(b+d) = 4(400+250) = 2600mm

$\therefore\ \tau_v = \frac{804.94}{2600\times250}$ = 1.29N/mm^2

Permissible stress = ks τ_c

= $0.25\sqrt{fck}$

= $0.25\sqrt{25}$ = 1.25 N/mm^2

Actual shear stress slightly greater than permissible

Hence increase the effective depth slightly ie to 260mm

		Provide overall depth = 300mm Provide 12mm Ø bars @ 50mm c/c in both direction.			