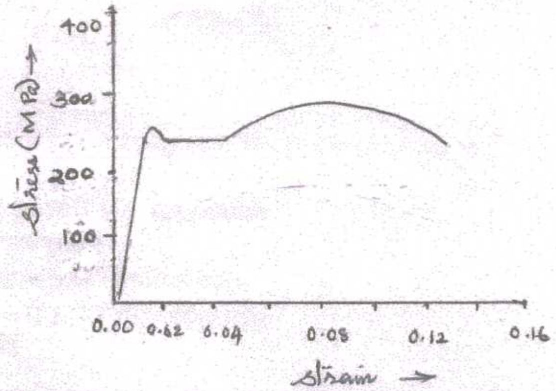
(261) 13 NOV 23 24

SCHEME OF VALUATION

Revision : 2015

Course Title : STRUCTURAL DESIGN I (Scoring Indications) Course Code : 5015

Qn NO	Scoring Indicators	Split up	Sub total	Total
	PART – A			
	(Max.marks : 10)			
I				
1)	**Workability means the ease of placement and workable concrete means the concrete which can be placed and can be compacted easily without any segregation.**	2		2
2)		2		2
3)	**The term bond refers to the adhession between concrete and steel which resist the slipping of steel bar from the concrete.**	2		2
4)	**One way slab ----- ly/lx ratio is greater than 2**	1		
	Two way slab ----- ly/lx ratio is lessthan 2	1		2
	Where ly – length of longer span, lx – length of shorter span.			
5)	**Column is considered as short when the slenderness ratio(λ)is lessthan or equal to 12.**	1		
	If the slenderness ratio(λ) is greater than 12 ,it is called as short column.	1		2
	PART - B			
II	**(Max. marks:30)**			
1)	**(i) To take up all the tensile stresses developed in the structure.**			
	(ii) To increase the strength of concrete sections.			
	(iii) To prevent the propagation of cracks developed due to temperature and shrinkage stresses.			
	(iv) To make the sections thinner as compare to plain concrete section.	$(1\frac{1}{2})$	x4	6

Q. No.	Answer	Marks		Total
II				
2)	**PROCEDURE**			
	Calculate shear force V_u			
	Determine nominal shear stress (τ_v)			
	$\tau_v = Vu/bd$			
	Depending on the grade of concrete and percentage of steel			
	(100.Ast/bd).Find out shear strength of concrete(τ_c)			
	Compare τ_v and τ_{cmax}, if $\tau_v > \tau_{cmax}$ redesign the section.	2		
	Compare τ_v and τ_c			
	If $\tau_v < \tau_c$: Nominal shear reinforcement is to be provided in the form of vertical stirrups.			
	$A_{sv}/b.s_v \geq 0.4/0.87\, f_y$	2		
	If $\tau_v > \tau_c$: Shear reinforcement is to be designed as follows:			
	$V_{us} = V_u - \tau_c bd$			
	If vertical stirrups are provided then their spacing			
	$V_{us} = 0.87 f_y . A_{sv} . d/S_v$	2		6
3) 3	**(i) Development length (Ld) of reinforcement: It is the minimum length of the bar which must be embedded in concrete beyond any section to develop its full strength.**			
	$Ld \geq 0.87 fy . \phi / 4\tau bd$	3		
	(ii) Curtailment of bars : The extra part that is removed from the reinforcement which forms the curtailed reinforcement. The curtailed bars in flexural members are extended for a distance equal to 12 times the dia. of the bar	3		6
4)	**(i) To distribute the concentrated loads coming on the slab**	2		
	(ii) To protect against shrinkage and tempt. stresses.	2		
	(iii) To keep the main bar in position.	2		6
5) 5	**(i)Interior panels** **(ii) One short edge continuous**			
	(iii) One long edge discontinuous **(iv) two adjacent edges discontinuous**			
	(v) Two short edges discontinuous **(vi) two long edges discontinuous**			

II	(vii) Three edges discontinuous (one long edge continuos) (viii) Three edges discontinuous (ix) Four edges discontinuous	1x6		6
6)	Assume suitable % of A_{sc} ($A_{sc} = pA_g$) Determine A_c in terms of A_g $A_c = A_g - A_{sc}$ Calculate A_g as follows:	2		
	$Pu = 0.4\ f_{ck}(A_g - A_{sc}) + 0.67f_y.A_{sc}$ Calculate dimensions of column as follows:	2		
	For square column ,$B^2 = A_g$ For rectangular column, $B \times D = A_g$ (assume B and calculate D) Provide area of reinforcement (A_{sc}) Design lateralties as per IS specifications.	2		6
7)	Footing are the important part of foundation construction. They are typically made of concrete with reinforcement. The purpose of footing is to support the foundation and prevent settling.	2		
	Classification: (i)Isolated footings: (a) Square footings (b) Rectangular footings (c) Circular footings (ii) Combined footings : (a) Rectangular (b) Oval (c) Trapezoidal	2		
	(iii) Continuous or wall footings or strip footings (iv) Strap footings (v) Raft or mat footings (vi) Pile footings (vii) Well foundations	2		6

PART – C

(Max:marks :60)

MODULE – I

III

a) **Balanced section:**

In this section the steel reinforcement reaches the yield strain ((0.87fy/Es)+0.002) at the same time as the concrete reaches the ultimate strain value of 0.0035

$X_u/d = X_{umax}/d$ 2

Under reinforced section:

In this case , the steel fails first by reaching its yield strain value, while in concrete the ultimate strain has not reached. steel is ductile material and it gives sufficient warning before failure, hence the under reinforced sections are preferred by designers.

$X_u/d < X_{umax}/d$ 2

Over reinforced section:

The over reinforced section is that in which strain in concrete reaches its ultimate value earlier than the steel. This means that over reinforced section fails by crushing failure of concrete.

$X_u/d > X_{umax}/d$ 2 6

b) b = 250mm, d = 500mm,

$Ast = 4\pi \times 20^2/4 = 1256.63mm^2$ 2

Depth of NA, $X_u = 0.87f_y A_{st}/0.36f_{ck} \times b$

$= (0.87 \times 415 \times 1256.63)/(0.36 \times 20 \times 250)$

$= 252.059mm$ 2

$X_{umax}/d = 0.48$

$X_{umax} = 240mm$

$X_u > X_{umax}$, hence the section is over reinforced 2

	Moment of resistance,			
	$M_{ulim} = 0.36X_{umax}/d(1\text{-}0.42\ X_{umax}/d)\ bd^2f_{ck}$			
	$= 172.45$ KNm	3		9
	OR			
IV a)	For the given grade of concrete and steel find the depth of NA of the section:			
	$X_u = 0.87f_y\ A_{st}/0.36f_{ck}\ b$			
	Find the limiting value of the NA (X_{umax}) from IS 456			
	Compare X_u and X_{umax}			
	If $X_u < X_{umax}$, the beam is under reinforced then MR,			
	$M_u = 0.87f_y.A_{st}.d(1\text{-}0.42X_u/d)$	2		
	If $X_u = X_{umax}$, the beam is designed as balanced section then MR			
	$M_{ulim} = 0.36\ f_{ck}\ X_{umax}/d(1\text{-}\ 0.42X_{umax}/d)\ bd^2$	2		
	If $X_u > X_{umax}$, the MR of the section is equal to M_{ulim} but the code recommends that the section is to be redesigned .	2		6
b)	b= 230 mm, d = 500 mm , $f_{ck} = 20N/mm^2$, $f_y = 415\ N/mm^2$			
	Moment of resistance,			
	$M_u = 0.87f_y\ A_{st}\ d(1\text{-}\ A_{st}\ f_y/bdf_{ck})$	2		
	$220\ x10^6 = 0.87 \times 415\ A_{st} \times 500[1\text{-}\ (A_{st} \times 415)/(230 \times 500 \times 20)]$			
	$A_{st} = 1809.86mm^2$	5		
	Check min.Ast : $A_s/bd = 0.85/f_y$			
	$A_s = 235.54mm^2 < 1809.86mm^2$. Hence safe	1		
	Check max.Ast : $0.04bD = 0.04 \times 230 \times 535$			
	$= 4922mm^2 > 1809.86mm^2$. Hence safe	1		9

MODULE – II

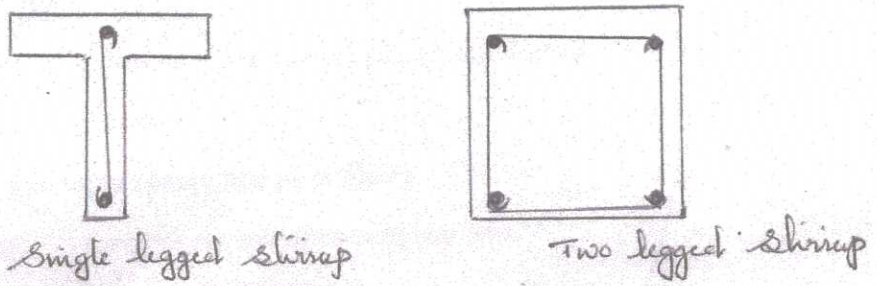
V a) **Types of shear reinforcement :**

(i) **Vertical stirrups.**

(ii) **Bent up bars along with stirrups.**

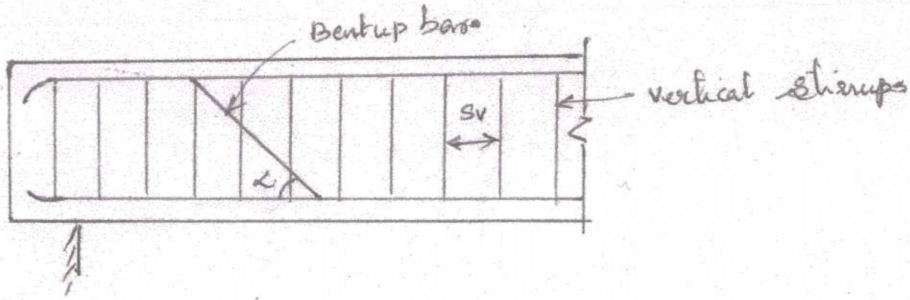
(iii) **Inclined stirrups.** 3

Vertical stirrups



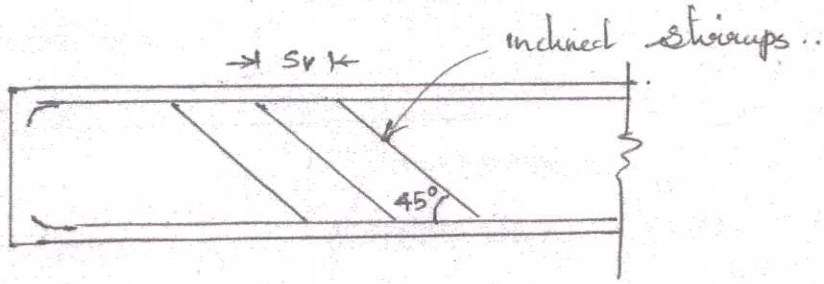
1

Bent up bars along with stirrups



1

Inclined stirrups



1 6

V b)	$bf = 740$ mm, $d = 400$ mm, $bw = 240$ mm, $Df = 100$ mm $fy = 250\ N/mm^2$,			
	$fck = 15N/mm^2$	2		
	$Ast = (5x\pi x20^2)/4 = 1570.79\ mm^2$			
	NA lies in the flange	2		
	$X_u = (0.87f_y.A_{st})/(0.36\ f_{ck}.b_f) = 85.49$ mm			
	$X_u < D_f$, hence considered as rectangular section.	2		
	$X_{umax}/d = 0.53$ $X_{umax} = 212$ mm			
	$X_u < X_{umax}$ under reinforced section.	3		9
	$M_u = 0.87f_y.A_{st}.d[1-(f_y.A_{st})/(f_{ck}.b.d)]$			
	$= \underline{124.57\ KNm}$			
	OR			
VI a)	$b_w = 250mm$ $b_f = 1600mm$ $d = 350mm$ $D_f = 100mm$			
	$f_{ck} = 20N/mm^2$, $f_y = 500N/mm^2$			
	Limiting depth of NA, (X_{umax}):	2		
	$X_{umax} = 0.46d = 161mm$			
	$D_f/d = 100/350 = 0.28 > 0.2$. Since $D_f/d > 0.2$,			
	$Y_f = 0.15X_{umax} + 0.65D_f = 89.15mm$.	2		
	Limiting MR (M_{ulim}):			
	$X_{umax}/d = 0.46$			
	$M_{ulim} = 0.36X_{umax}/d[1-(0.42\ X_{umax}/d)]f_{ck}.b_w.d^2 + 0.45f_{ck}(b_f-b_w)Y_f[d-(Y_f/2)]$	3		7
	$= \underline{412.66KNm}$			

VI b) b = 300 mm , d = 550mm,

$w = 28KN/m$, $f_{ck} = 20N/mm^2$, $f_y = 415 N/mm^2$

$V_u = 1.5(wl/_2) = 105KN$ 2

Nominal shear stress, $\tau_v = V_u/bd = 0.63N/mm^2$

τ_c max = 2.8 N/mm^2 $\tau_v < \tau_{cmax}$

% of steel = $100.A_{st}/bd = 0.76$

$\tau_c = 0.5624 N/mm^2$ 2

$\tau_v > \tau_c$ $\therefore$ shear reinforcement is provided

$V_{us} = V_u - \tau_c.bd = 12204 N$

Assuming 8 mm dia. two legged stirrups

$A_{sv} = (2x8^2x\pi)/4 = 100.54mm^2$

Vus = (0.87fy.Asv.d)/Sv

Sv = (0.87 fy.Asv.d)/Vu

= 1635.93mm 2

Check :

(i) 0.75 d = 0.75x550 = 412.5mm

(ii) 300 mm

(iii) 8mm dia. two legged stirrups @300 mm c/c 2 8

MODULE – III

VII ly/lx =2.33 > 2 ….one way slab

Assume, D=150mm, d = 150-25 = 125m

Effective span (l)

It should be the least of the following:

(i) c/c distance = 3.2 m

(ii) clear span + eff.depth =3.125m

$\therefore$ l = 3.125m 1

Design load (Wu), factored moment (Mu) and shear force (Vu)

Self wt. of slab = 0.15x1x25 = 3.75KN/m2
L.L = 6KN/m
Total load, W = 9.75 KN/m2

Factored moment = Mu = $1.5(W.l^2/8)$ = 17.85 KN/m^2

Factored SF, Vu = (9.75x3.125)/2 = 15.23 KN
Check for d:
Mu = Qfck bd2, Q = 0.138
$d_{req.}$ = 80.42mm < $d_{pro.}$ Hence d = 125mm — 2

Area of tensile reinforcement

Mu = 0.87 fy Ast d [1-(Ast fy)/fck bd)] — 2

A_{st} = 427.71mm^2

Check Ast:
Min.Ast, 0.12%Bd = 180mm^2 < 427.71mm^2

Spacing: 1000ast/Ast
Provided 10mmϕ bars, Spacing = 183.6mm = 180 mm
Check spacing: Min. of the following.
(i) 3d = 375mm — 1
(ii) 300 mm
(iii) 180 mm

∴ Provide 10mmϕ bars @ 180 mm c/c in shorter direction.

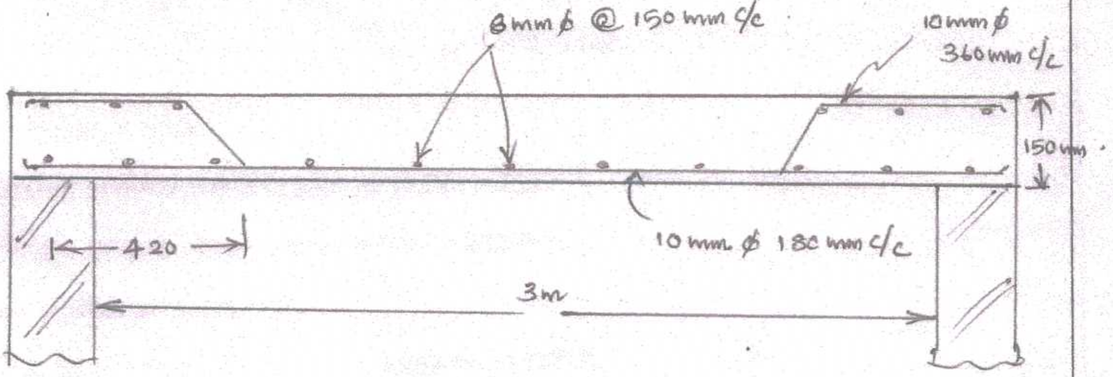
Ast pro. = 436.32mm2
Ast at support = 218.16mm2
l/7 = 3000/7 = 428.57mm = 430mm
Bending alternate bars at 420mm from centre of support.
Distribution steel:
Ast = 180mm2, using 6mm ϕ bars, ast = 28.27mm2
Spacing = (1000ast)/Ast = 157mm = 150mm — 1
∴ provide 6mmϕ @150mm c/c in longer direction

Check for shear:
Vu = 22.8x10^3N
τv = Vu/bd = 0.18N/mm2, τcmax = 2.8N/mm2 %steel = 0.17, τc = 0.296N/mm2, k=1.224 — 2
τc for slab = kτc = 0.36 N/mm2 > τv hence safe

Check for development length:

Ld = (ϕ. 0.87 fy)/4τbd = 470.1mm

(Mu/Vu) + Lo = 415.78 mm. > Ld hence OK — 2



(Fig.) 4 15

✓III Imposed load = 1800N/m2

Assume D =150mm, d= 125mm

Design load and factored moment

Self wt. of slab =0.15x1x25000 = 3750N/m

Imposed load = 1800x1 =1800N/m

Total load, W = 5550 N/m $W_u = 1.5 \times 5550 = 8325$N/m

$M_u = W_u.l^2/2 = 6.504 \times 10^6$ Nmm

$V_u = W_u.l = 8.325 \times 1.25 = 10406.25$ **N** 2

Minimum effective depth required

Xumax/d = 0.48

$M_u = Qf_{ck}.bd^2$, **Q = 2.76**

d_{req} **= 49mm < 125mm. Hence ok. ∴ The section is under reinforced** 1

Area of steel

$M_u = 0.87\ f_y\ A_{st}\ d\ [1-(f_y\ A_{st})/(bd\ f_{ck})]$

$6.504 \times 10^6 = 0.87 \times 415 \times 125\ A_{st}[1-(415 \times A_{st})/(1000 \times 125 \times 20)]$

Ast = 148mm² 2

Check for min.A_{st}

= 0.12Bd/100 =(0.12x1000x150)/100 = 180mm²

180mm² > 148mm²

- Providing $A_{st} = 180mm^2$

  Using 8mmϕ bar $A_\phi = \pi/_4 x8^2 = 50.3mm^2$

  Spacing of 8mm bar = (1000x50.3)/180 = 279mm say 270mm.

Max. spacing is limited to

(i) 3d = 3x100 = 300 mm

(ii) 300 mm

- Provide 8 mm ϕ @ 270 mm c/c as main steel

  Also providing 8 mm ϕ @ 270 mm c/c in other direction also as distribution reinforcement. 2

<u>Check for shear</u>

$V_u = 4617.2$ N

A_{st} provided =(1000x50.3)/270 =186.3 mm^2

Nominal shear stress, $\tau_v = V_u/bd = 0.08$ N/mm^2 , Pt = 100.Ast/bd = 0.15%

$\tau_c = 0.28$N/mm^2

K = 1.3

$k.\tau_c = 0.36$ N/mm^2 > τ_v. Hence OK. 2

<u>Check for development length</u>

$L_d = \phi.(0.87\ fy)/4\tau_{bd}$ =(8x0.87x415)/(4x1.6x1.2)

L_d = 376 mm

Therefore extending the bars into the support after giving a 90^0 bend for a distance 390mm(280+110) as shown in fig. 2

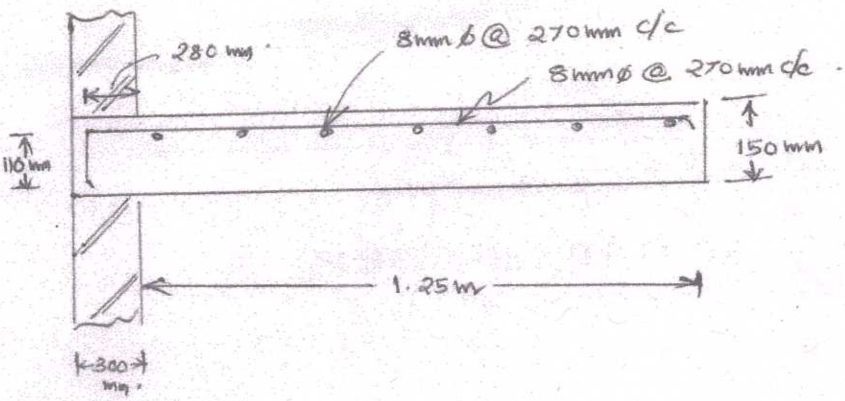


Fig. 4 15

MODULE – IV

IX a) The IS code recommendations for lateral and helical reinforcement are as follows.

Diameter of lateral ties : The dia.should be greater than:

(i) ¼ th of the dia. of largest longitudinal bar.

(ii) 6 mm

Pitch of lateral ties : The pitch should not be greater than:

(i) Least lateral dimension of the column.

(ii) 16 times the dia. of the smallest long.bar.

(iii) 300mm. — 3

Diameter of helical reinforcement : The dia.should be greater than

(i) ¼ th of dia. of the largest long.bar.

(ii) 6 mm.

Pitch of helical reinforcement :

The pitch should not be more than

(i) 75mm

(ii) 1/6 th of the dia.of core of concrete.

The pitch should not be lessthan

(i) 25 mm.

(ii) 3 times the dia.of steel bar forming the helix. — 3 — 6

IX b) $Pu = 1400 x 1.5 = 2100$ KN

$f_{ck} = 25 N/mm^2$, $f_y = 500 N/mm^2$

For short axial load,

$$Pu = 0.4\, f_{ck}\, Ac + 0.67 f_y A_{sc}$$ — 1

Assuming 1% steel

$$A_{sc} = 0.01A_g, \quad A_c = A_g - 0.01A_g = 0.99A_g$$

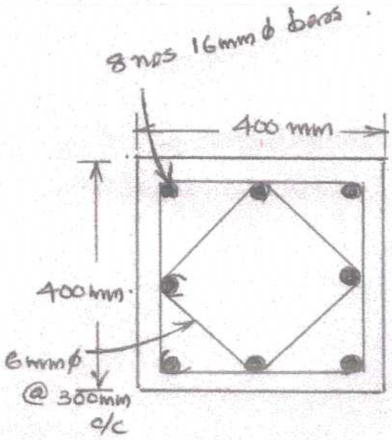
$$2100x103 = 0.4x25x0.99A_g + 0.67x500x0.01A_g$$

$$A_g = 158490.56 mm^2$$

Provide 400x400mm column

$$A_{sc} = 1/100 x A_g = 1600 mm^2$$ — 1

Using 16mmφ bars.
No. of bars = $1600/(\pi/4 \times 16^2) = 7.95 = 8$ nos.
∴ Provide 8-16mmφ bars as shown in fig. 2



Lateral ties:

The dia.of ties should not be less than
- (i) ¼ x16 = 4mm
- (ii) 6 mm

Using 8 mm dia.ties.
The pitch of ties should not be less than following:

- (i) Least lateral dimension = 400mm
- (ii) 16x16 = 256 mm
- (iii) 300 mm

fig. Fig.3 9

∴ Provide 8 mm φ @ 250 mm c/c as double ties. 2

OR

Wc = 900 KN, Bearing capacity, q_u = 190KN/m², f_{ck} = 20N/mm², f_y = 415 N/mm²

Load calculation :

Wc =900 KN, Self wt. of footing, Wf = 10% of Wc = 90 KN

Wc+Wf = 990 KN

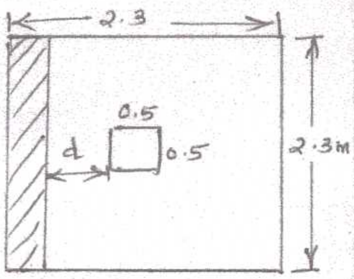


fig.

Area of footing

$A = (W_c + W_f)/q_u = 5.21\text{m}^2$

Side of square = $\sqrt{5.21}$ = 2.28 m say 2.3 m 1

Factored soil pressure due to column load only:

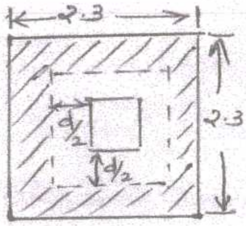
$P_u = (1.5 \times 900)/(2.3 \times 2.3)$
$= 255.19\text{KN/m}^2$

<u>Depth of footing by one way shear criterion:</u>

Shear force due to factored soil pressure at critical section
$= 2.3 \times [((2.3-0.5)/2)-d] \times 255.19$
$= 586.937\,(0.9 - d)$ ....(i)

Assuming 0.2% steel, $\tau_c = 0.32\text{N/mm}^2$
S.F resisted by the section = $\tau_c X d$ = 0.32x103x2.3xd = 736d.......(ii)
Equating (i) & (ii)
$d = 0.399\text{m}$ 3

Depth of footing by two way shear:



Considering critical section is at d/2 from the face of column.

Perimeter of critical section = 4(0.5+d) = 2+4d

(fig.)

S.F at critical section

$= 255.19(2.3 \times 2.3-(0.5+d)^2)$

$= 1286.157-255.19d^2-255.19d$ ....(iii)

S.F resisted by the critical section

Max. allowable shear stress = $0.25\sqrt{fck}$ = 1.118N/mm^2 = 1118 KN/ m^2

SF resisted = 1118(2+4d)d = $2236d + 4472d^2$ ... .(iv)

Equating (iii) &(iv)

d = 0.321 m | 3

Depth of footing by BM criterion

Critical section is at the face of column.

BM at the critical section

$Mu = Pu[(x-a)/2] [(x-a)/4]$

$= 255.19 \times 2.3([2.3-0.5)/2][(2.3-0.5)/4]$

$= 237.7 \times 10^6$ Nmm ....(v)

MR of critical section ,

$MU = Qf_{ck}bd^2 = 0.136 \times 20 \times 2300 \times d^2 = 6256d^2$ ....(vi)

Equating (v) & (vi)

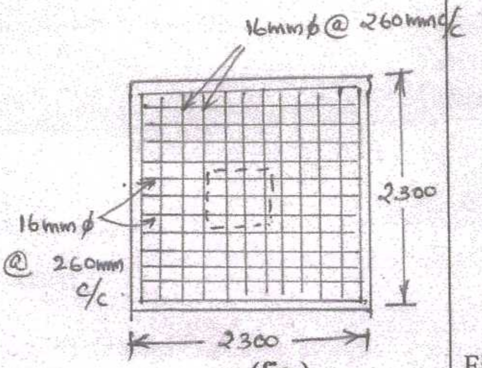
d = 0.192 m

highest value of d =0.399 m = 400 mm

Overall depth | 3

D = 400+8+50 = 458 = 460 mm

Area of steel reinforcement



$Mu = 0.87 \, fy \, Ast \, d \, [1-(Ast \, fy)/(bd \, fck)]$

Ast = 1773.835 mm2

Check min. Ast

= 0.12x2300x460/100

= 1269.6mm2 < Ast hence safe

Using 16 mm dia.bars

Spacing =(bxast)/Ast = 260mm

(fig.) | Fig.3

Provide 16 mmϕ bars@260 mm c/c in each direction | 2 | 15