LECTURE NOTE

On

STRUCTURAL DESIGN-I

(4th SEM. Civil Engineering)

Prepared By:

SRI PADMA LOCHAN BEHERA

SR.LECTURER (Civil Engg.)

Government Polytechnic, Sonepur

STRUCTURAL DESIGN - II

Dt: 18/01/24

RCC - Reinforced Cement Concrete
PCC - Plain Cement Concrete

→ To increase the tensile strength of plain cement-concrete, reinforcement is provided with the PCC which is known as Reinforced Cement Concrete or RCC.

Characteristic Strength →

→ It is defined as the strength of material below which not more than 5%. of test results are expected to fail.

→ It's unit is N/mm^2 or MPa.

Grade of Concrete →

M_{10}, M_{15}, M_{20}, M_{25}, M_{30}, M_{35} .... M_{80}

M = Mix

10, 15, 20 .... → characteristic strength in N/mm^2

Nominal mix
Design mix

Nominal mix - M_{10} = 1:3:6
M_{15} = 1:2:4
M_{20} = 1:1.5:3

Grade of Steel →

① Mild steel - Fe 250
② High yield strength deformed bar (HYSD)

① Fe - Steel 250 - yield strength in N/mm^2
② HYSD
Fe 415, Fe500, Fe550, Fe5500

Objectives of Design →   Dt. 29/01/24

The structural design is to be done for the purpose of following requirements.

① **Stability** →

The structure must be able to resist overturning, sliding or bulking under the action of load.

② **Strength** →

The structure must be able to resist safely the stresses induced due to the loads including environmental load.

③ **Serviceability** →

The structure must ensure satisfactory performance under the service load i.e providing stifness impermeability and durability.

Q> Methods of Design →   Dt 30/01/24

Based on design consideration i.e safety serviceability and economy.

3 Methods of design

① Working stress method
② Ultimate load Method
③ Limit state method

① **Working Stress Method** →

→ This is a traditional method of design adopted of concrete and steel structure.

→ This method assumes that the structural materials behaves in a linear elastic manner and safety can be ensured by restricting the stress in the material develop due to expected working load.

→ The working load is decided by limiting stress in concrete and steel at which the materials falls.

Disadvantages of WSM →

→ The main assumption of WSM to keep the stress with in permissible limit is not found to be realistic.

→ The long turn effect of creep and shrinkage are neglected.

→ WSM fails to differentiate betn different types of load that act simultaneously.

② Ultimate load Method → Dt 31/01/24

→ In this method the stress condition at the time of collapse of structure is analysed and the non-linear stress strain curve of steel and concrete are considered.

→ The Ultimate load is sum known multiple of working load which is called load factor.

$$\text{load factor} = \frac{\text{Ultimate load}}{\text{working load}}$$

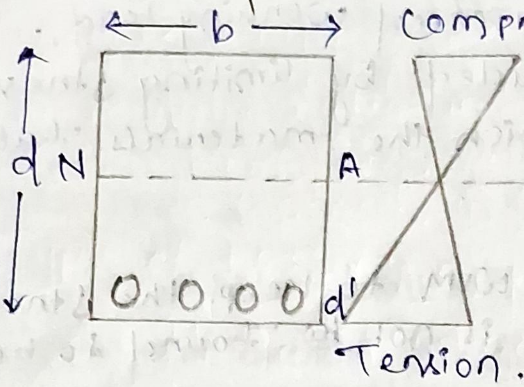
→ This method allows to use different load factor for different types of load that is dead load, live load, wind load, Earthquake load etc.

Disadvantages of ULM →

→ This method does not consider the serviceability criteria of deflection and cracking.

→ This method does not consider the effect of creep and shrinkage.

Q) Reinforced concrete structure and its behaviour →

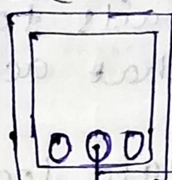


b = width of beam
D = overall depth
d = effective depth
d' = effective cover

→ σ_{cbc} = Compressive stress in concrete

Dt. 11/02/24

→ σ_{st} = Tensile stress in steel



Q) Effective Cover →

→ It is the distance from the centre of reinforcement to the outer layer of concrete.

→ Effective cover is provided to protect the reinforcement from corrision and gives a aesthetic look to the structure.

Q) Neutral Axis →

Neutral axis is a horizontal line across the crossection of a beam where stress is zero or stress changes from compressive to tensile.

N_c → Critical depth of neutral axis from top of section.

Q) Modulus of Rupture →

→ The maximum tensile stress reached in the extreme fibre of concrete beam is known as modulus of rupture.

→ It is denoted by f_{cr}.

$$f_{cr} = 0.7\sqrt{f_{ck}}$$

f_{ck} = Characteristic of concrete

(a) Modular Ratio →

→ It is the ratio of modulus of elasticity of steel to that of concrete.

→ It is denoted by $m = \frac{E_s}{E_c}$

E_s = Modulus of elasticity of steel

Elasticity of steel = 2.1×10^5 MPa

E_c = Modulus of elasticity of concrete

$5000\sqrt{f_{ck}}$ MPa

Q. Determine the modular ratio of a RC section of grade M_{25}?

Ans

$E_s = 2.1 \times 10^5$ MPa

$E_c = 5000\sqrt{f_{ck}}$

$M = \frac{E_s}{E_c}$

$E_s = 2.1 \times 10^5$

$E_c = 5000\sqrt{f_{ck}}$

$= 5000 \times \sqrt{25}$

$= 5000 \times 5$

$= 25000$

$M = \frac{2.1 \times 10^5}{25000} = 8.4$

Assumption for design of members →

(a) At any cross-sections before bending remain plane after bending.

(b) All tensile stresses are taken up by reinforcement (steel bars) and none by concrete, except as otherwise specifically permitted.

(c) The stress-strain relation-ship of steel and concrete under working loads, is a straight line.

(d) The modular ratio m has the value $\frac{280}{3\sigma_{cbc}}$

σ_{cbc} = Permissible value of stress in concrete in bending compression.

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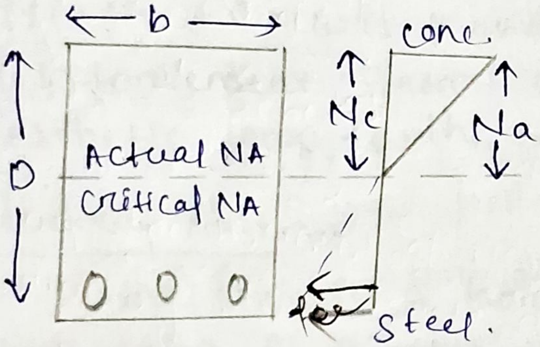
Types of RC Section →

It is depending on the amount of reinforcement provided and the position of neutral axis the RC section each of 3 types.

1. Balanced section
2. Under Reinforced Section
3. Over reinforced section

(1) Balanced section ⇒



Nc = Critical Neutral axis Depth

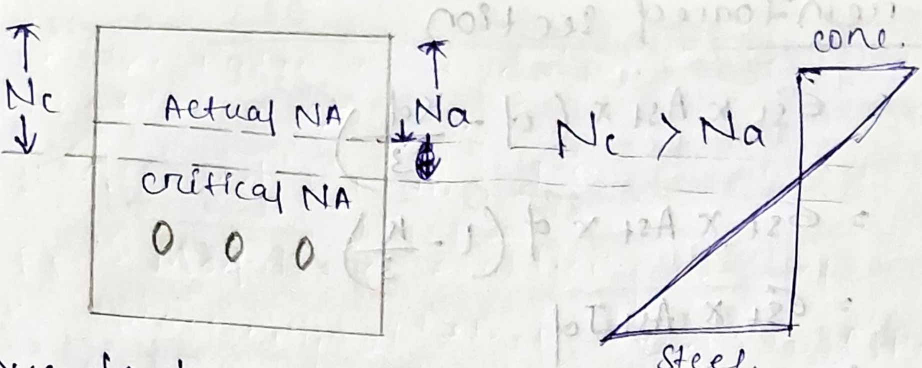
Na = Actual Neutral axis Depth

→ In a RC section if the Reinforcement provided is equals to the actual requirement of reinforcement, then it is called a balanced section.

→ In balanced section Na = Nc

(2) Under reinforced section ⇒

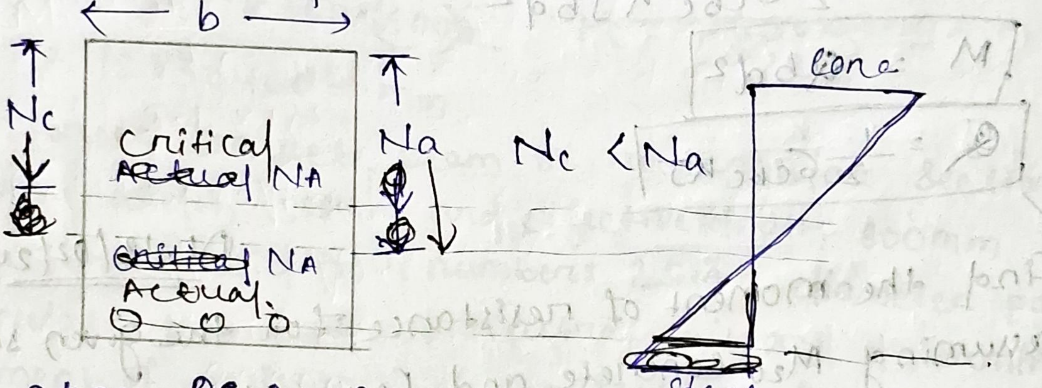
In a RC section if the reinforcement provided is less than the require reinforcement then it is called under reinforced section.



Due to less reinforcement the permissible stress in steel reached earlier than concrete. So Nc becomes greater than Na.

③ Over Reinforced Section →

In a RC section if the reinforcement provided is greater than the require reinforcement then the section is called over reinforced section.



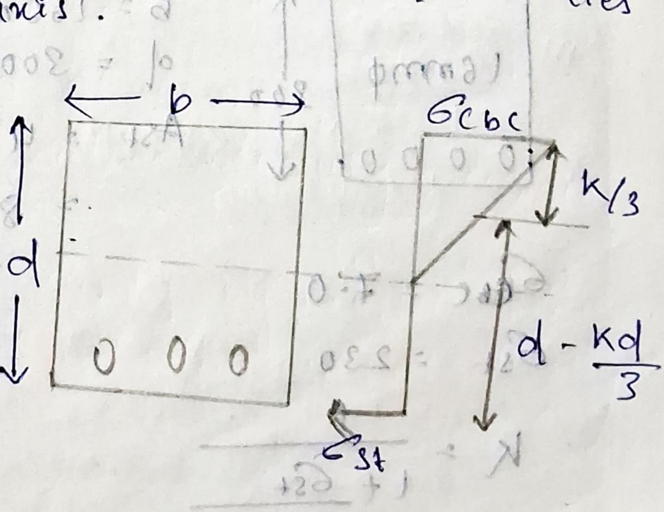
→ In above RC section the critical neutral axis lies above actual neutral axis.

Depth of NA

Depth factor

$$k = \frac{1}{1 + \frac{\sigma_{st}}{m\sigma_{cbc}}}$$

$$m = \frac{280}{3\sigma_{cbc}}$$



→ Under reinforced section

$$M.R = \sigma_{st} \times A_{st} \times \left(d - \frac{Kd}{3}\right)$$

$$= \sigma_{st} \times A_{st} \times d\left(1 - \frac{K}{3}\right)$$

$$= \sigma_{st} \times A_{st} J d$$

A_{st} = Area of steel reinforcement

→ Over reinforced section / Balanced section →

$$M.R = \frac{1}{2} \sigma_{cbc}\, b \cdot Kd \left(d - \frac{Kd}{3}\right)$$

$$= \frac{1}{2} \sigma_{cbc}\, bKd \times d\left(1 - \frac{K}{3}\right)$$

$$= \frac{1}{2} \sigma_{cbc} K J b d^2$$

$$M = Q b d^2$$

$$Q = \frac{1}{2} \sigma_{cbc} K J$$

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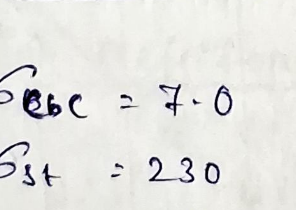
Q) Find the moment of resistance for the given section assuming M20 concrete and Fe415 steel.



$b = 160$ mm

$d = 300$ mm

$A_{st} = 4 \times \frac{\pi}{4} \times (16)^2$

$= 804.25$

$\sigma_{cbc} = 7.0$

$\sigma_{st} = 230$

$$K = \frac{1}{1 + \frac{\sigma_{st}}{m\sigma_{cbc}}}$$

$m = \frac{280}{3\sigma_{cbc}} = \frac{280}{3 \times 7} = 13.33$

$K = \frac{1}{1 + \frac{230}{13.33 \times 7}} = 0.288$

$M = Qbd^2$

$Q = \frac{1}{2} \sigma_{cbc} kJ$

$J = 1 - \frac{k}{3}$

$= 1 - \frac{0.28}{3} = 0.91$

$Q = \frac{1}{2} \times 7 \times 0.28 \times 0.91$

$M = 0.891 \times 160 \times (300)^2$ ~~M = 128304~~

$= 12830400 \text{ N.mm}$

Q. Reinforced concrete beam of rectangular section having width 300mm and effective depth 600mm reinforced width 4 numbers 25mm diameter path. Calculate the depth of neutral axis and determine the moment of resistance of the section. Assuming M_{25} concrete and Fe_{415} steel.

Ans

$b = 300\text{mm}$

$d = 600\text{mm}$

$A_{st} = 4 \times \frac{\pi}{4} \times (25)^2$

$= 1963.49$

$\sigma_{cbc} = 8.5$

$\sigma_{st} = 230$

$$k = \frac{1}{1 + \frac{\sigma_{st}}{m\sigma_{cbc}}}$$

$$= \frac{1}{1 + \frac{230}{m\sigma_{cbc}}}$$

$$m = \frac{280}{3\sigma_{cbc}} = \frac{280}{3 \times 8.5} = 10.98$$

$$k = \frac{1}{1 + \frac{230}{10.98 \times 8.5}} = 0.288$$

$M = Qbd^2$

$Q = \frac{1}{2}\sigma_{cbc} kJ$

$J = 1 - \frac{k}{3}$

$= 1 - \frac{0.28}{3} = 0.91$

$Q = \frac{1}{2} \times 8.5 \times 0.28 \times 0.91$

$= 1.08$

~~at 1.08~~

$M = Qbd^2$

$= 1.08 \times 300 \times (600)^2$

$= 116640000$

Dt. 16/02/24

Design of beam by WSM →

Q. Design a concrete beam of span 6m. to carry an UDL 15 KN/m. Assume M20 Concrete and Fe415 steel.

Ans

$w = 15 \, kN/m$

$L = 6mm$

$M = \frac{wl^2}{8} = \frac{15 \times 6^2}{8}$ (simply supported beam under UDL)

$= 67.5 \, kN/m.$

$= 67.5 \times 10^6 \, N/mm$

M20, Fe415

$b = ?$, $d = ?$, $A_{st} = ?$

$M = Q b d^2$, $Q = \frac{1}{2} \sigma_{cbc} k J$

$\sigma_{cbc} = 7$ $\sigma_{st} = 230$

$k = \frac{1}{1 + \frac{\sigma_{st}}{m \sigma_{cbc}}}$, $m = \frac{280}{3 \sigma_{cbc}} = \frac{280}{3 \times 7.0} = 13.33$

$= \frac{1}{1 + \frac{230}{13.33 \times 7.0}}$

$M = Q b d^2$

$J = 1 - \frac{k}{3}$

$= 0.91$

$Q = \frac{1}{2} \times 7.0 \times 0.28 \times 0.91 = 0.89$

$M = Q b d^2$

$b = \frac{d}{2}$

$67.5 \times 10^6 = 0.891 \times \frac{d}{2} \times d^2$

$\Rightarrow d^3 = \frac{67.5 \times 10^6 \times 2}{0.891}$

$\Rightarrow d = \sqrt[3]{\frac{67.5 \times 10^6 \times 2}{0.891}}$

$= 533.11$

$= 540mm$

$b = \frac{d}{2} = \frac{540}{2} = 270mm$

Cover $= 30mm$

$b = 540 + 30 = 570mm$

$M = \sigma_{st} A_{st} J d$

$67.5 \times 10^6 = 230 \times A_{st} \times 0.91 \times 540$

$\Rightarrow A_{st} = \frac{67.5 \times 10^6}{230 \times 0.91 \times 540}$

$= 597.221 mm^2$

③ Limit State Method ⇒

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In this method the structures are will be design to resist all the load that comes on the structure throughout its life, and also satisfy the serviceability conditions such as deflection and cracking.

Limit state →

Limit states are the states beyond which the structure no longer satisfies the performance requirements for which it is ~~built~~ built.

→ It is Classified in to 2 Categories.
(i) Limit state of strength (Flexture, shear and Torsion)
(ii) Limit state of serviceability (Deflection and cracking)

Characteristics Strength ⇒ 2 Marks

It is defined as that value of the strength of material below which not more than 5% of test results are expected to fail.

Characteristics load ⇒

It is the value of load which has a 95% probability of not being exceded during the entire life of the structure.

Partial safety factor ⇒

~~It is the~~ In construction field there are various uncertainities and to deal with these a factor known as partial safety factor is used to access the design strength and load for the same design of structures.

→ Partial safety factor is denoted by γ.

$\gamma = 1.5$ for RCC
$= 1.15$ for steel st.

Design load = $f \cdot \gamma$

f = Characteristics load [working load

Load on structure ⇒

① Dead load → own weight of structure.

IS : 875 part - I

② Live load ~~or~~ Imposed load →

IS : 875 part - II

③ Wind load →

IS : 875 part - III

④ Snow load →

IS : 875 part - IV

⑤ Seismic load / Earthquake load →

~~IS : 1893~~ IS : 1893

Design requirements in LSM ⇒

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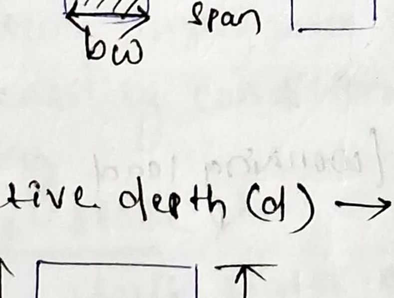
Ⓐ Effective span →



effective span = pressure L + bw

L + d

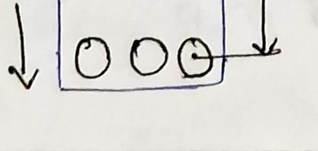
Where,

L = clear span

bw = support width

d = depth of slab / beam

Ⓑ Effective depth (d) →



④ Span to effective depth ratio →

Simply supported beam → 20

Continuous beam → 26

Cantilever beam → 7

Reinforcement →

→ Min^m reinforcement in beam is taken as $Ast = \frac{0.85bd}{fy}$

$$Ast = \frac{0.85bd}{fy}$$

Where,

Ast = min^m tension reinforcement

b = width of beam

d = effective depth

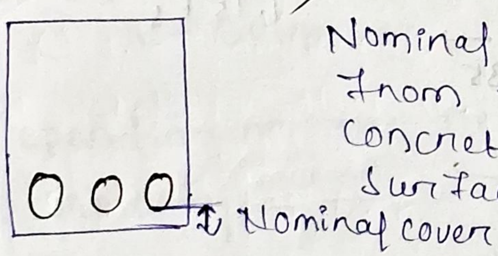
fy = strength of reinforcement

→ Max^m reinforcement = 0.04 bD

where, b = width of beam

D = overall depth of beam

Nominal cover ⇒



Nominal cover is defined as the distance from the outer surface of the concrete members to the outer surface of steel.

Slab → 20-25 mm

Beam → 20-30 mm

Column → 40-60 mm

Foundation → 50-75 mm.

Limit state of collapse →

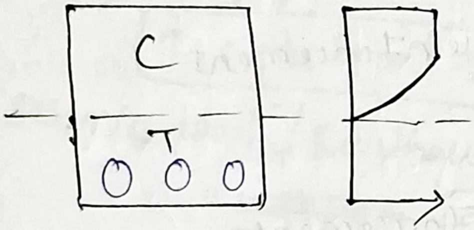
Ⓐ Flexure →

Assumptions (5 Marks)

1- Plane section normal to the axis remain plane after bending.

2- The max^m strength in concrete at the outermost compression fibre is taken as 0.0035.

3- The relationship betn compression stress distribution in concrete and the strain in ~~coe~~ concrete is assume to be a rectangle, trapezoid or parabola.

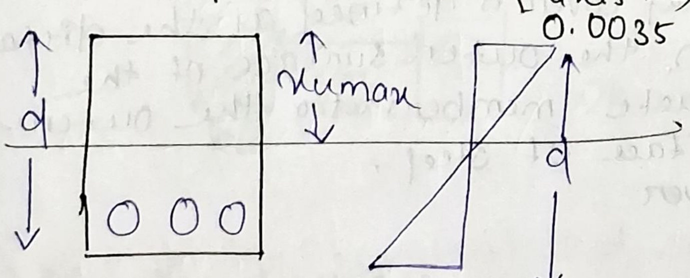


4- The tensile strength of concrete is ignored.

5- The stress in reinforcement is derived from the stress-strain curve of the type of steel used.

6- The max^m strain in the tension reinforcement are failure shall not be less than $\frac{f_y}{1.15 E_s} + 0.002$

Max^m depth of neutral axis →



$\frac{f_y}{1.15 E_s} + 0.002$

$$\frac{x_{umax}}{d} = \frac{0.0035}{\frac{f_y}{1.15E_s} - 0.002 + 0.0035}$$

$$= \frac{0.0035}{\frac{f_y}{1.15E_s} + 0.0055}$$

#

f_y	$\frac{x_{umax}}{d}$
250	0.53
415	0.48
500	0.46

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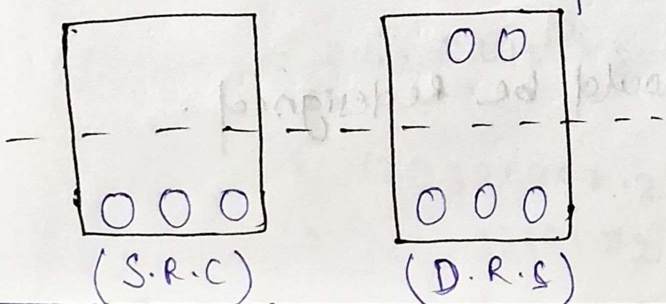
Types of Beam ⇒

⇒ Depending on the size of section beam is classified into 4 categories.

1. Rectangular Beam
2. Square Beam
3. T- Beam
4. L - Beam

⇒ Depending on the reinforcement provided the beam is of 2 types →

1. Single Reinforced Section (S.R.S)
2. Double Reinforced Section (D.R.S)



Single Reinforced Section →

1- Determine the depth of NA.

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

Where,

d = effective depth of beam
f_y = Strength of reinforcement
A_{st} = Area of Steel Reinforcement
f_{ck} = Grade of concrete
b = width of beam

	Fe250	Fe415	Fe500
$\frac{x_{umax}}{d}$ =	0.53	0.48	0.46

→ If $\frac{x_u}{d} < \frac{x_{umax}}{d}$

$$M_u = 0.87 f_y A_{st} d \left(1 - \frac{f_y A_{st}}{f_{ck} b d}\right)$$

→ If $\frac{x_u}{d} = \frac{x_{umax}}{d}$

$$M_u = 0.36 \frac{x_{umax}}{d} \left(1 - 0.42 \frac{x_{umax}}{d}\right) f_{ck} b d^2$$

→ If $\frac{x_u}{d} > \frac{x_{umax}}{d}$

then the section should be Redesigned.

Q Calculate the moment of resistance of a rectangular beam of size 300mm x 500mm reinforced with 4 numbers 16mm diameter bar. The concrete of grade M20 and reinforcement of grade Fe415 ?

Ans Given ;

$b = 300mm$

$D = 500mm$

$d' = 30mm$ (Assume)

$d = 500 - 30 = 470mm.$

Rod 4 no. 16 mm ϕ

$A_{st} = 4 \times \frac{\pi}{4} (d)^2 = 4 \times \frac{\pi}{4} \times (16)^2$

$= \frac{\pi}{4} (470)^2 = 804.24 \ mm^2$

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

$= \frac{0.87 \times 415 \times 804.24}{0.36 \times 20 \times 300 \times 470}$

$= 0.28$

For Fe415

$\frac{x_{umax}}{d} = 0.48$

then $\frac{x_u}{d} < \frac{x_{umax}}{d}$

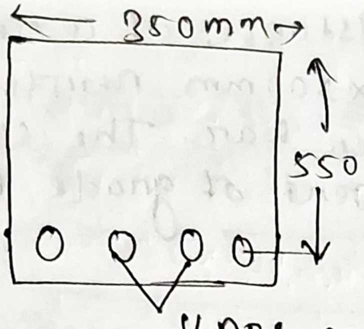
So, $M_u = 0.87 f_y A_{st} d \left(1 - \frac{f_y A_{st}}{f_{ck} b d}\right)$

$= 0.87 \times 415 \times 804.24 \times 470 \left(1 - \frac{415 \times 804.24}{20 \times 300 \times 470}\right)$

$= 120321957.2 \ N.mm$

$= 120.3219572 \ KN.m. = 120.32 \ KN.m$

Q. Dt 14/03/24



4 nos. 20mm ϕ

M25 concrete and Fe415 steel

Calculate the moment of resistance of the section.

Ans

Given,

$b = 350mm$.

$d = 550mm$.

~~Ast = π × (d)²~~

~~= π × (550)²~~

~~= 950331.7~~

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

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

$= \pi \times (20)^2$

$= 1256.63 \ mm^2$

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

$$= \frac{0.87 \times 415 \times \text{~~950331.7~~ } 1256.63}{0.36 \times 25 \times 350 \times 550}$$

$= 0.28$

For Fe415

$$\frac{x_{umax}}{d} = 0.48$$

then $\frac{x_u}{d} < \frac{x_{umax}}{d}$

So,

$$M_u = 0.87 f_y A_{st} d \left(1 - \frac{f_y A_{st}}{f_{ck} b d}\right)$$

$$= 0.87 \times 415 \times 1256.63 \times 550 \left(1 - \frac{415 \times 1256.63}{25 \times 350 \times 550}\right)$$

$$= 222497475.5 \text{ N.mm}$$

$$= 222.4974755 \text{ KN.m}$$

Design Single Reinforced Section →

1- Calculate the max^m bending moment from the load.

2- Assume $b = \frac{d}{2}$ and calculate b, d from the eq^n

Fe250 ⇒	$M_u = 0.149 f_{ck} b d^2$
Fe415 ⇒	$M_u = 0.138 f_{ck} b d^2$
Fe500 ⇒	$M_u = 0.133 f_{ck} b d^2$

(IMP)

3- Assume the value of effective cover and determine the overall depth of beam.

4- Calculate the area of reinforcement from the eq^n $M_u = 0.87 f_y A_{st} d \left(1 - \frac{f_y A_{st}}{f_{ck} b d}\right)$

5- Assume dia of reinforcement and find out the nos of reinforcement and spacing.

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Q. Design a simply supported beam of span of 6mt. Carrying an UDL of 30kN/mt. Using M20 concrete and Fe415 steel.

Ans

$w = 30 kN/mt.$

$L = 6 mt.$

$M = \frac{wl^2}{8} = \frac{30 \times (6)^2}{8}$

$= 135 \ kN.mt.$

mega watt = 10^6

Design moment (M_u) = 1.5×135 (multiply by Partial Safety Factor)

$= 202.5$ w.m.

$= 202.5 \times 10^6$

Assume $b = \frac{d}{2}$

$5x^2 + 6x + 9$

Fe415, $M_u = 0.138 \ f_{ck} b d^2$

$\Rightarrow 202.5 \times 10^6 = 0.138 \times 20 \times \frac{d}{2} \times (d)^2$

$\Rightarrow d^3 = \frac{202.5 \times 10^6 \times 2}{0.138 \times 20}$

$\Rightarrow d = \sqrt[3]{\frac{202.5 \times 10^6 \times 2}{0.138 \times 20}}$

$= 527.45 \simeq 530$ mm.

$\therefore b = \frac{d}{2} = \frac{530}{2} = 265 \simeq 270$ mm

Assume, $d' = 30m$

$D = d + d'$

$= 530 + 30 = 560$ mm

then, $M_u = 0.87 f_y A_{st} d \left(1 - \frac{f_y A_{st}}{f_{ck} b d}\right)$

$\Rightarrow 202.5 \times 10^6 = 0.87 \times 415 \times A_{st} \times 530 \left(1 - \frac{415 \times A_{st}}{20 \times 270 \times 530}\right)$

$\Rightarrow 202.5 \times 10^6 = 191356.5 A_{st} \left(1 - 1.45 \times 10^{-4} A_{st}\right)$

$\Rightarrow 202.5 \times 10^6 = 191356.5 A_{st} - 27.74 A_{st}^2$

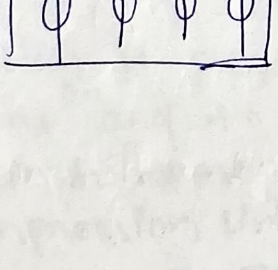
$\Rightarrow 27.74 A_{st}^2 - 191356.5 A_{st} + 202.5 \times 10^6 = 0$

$\Rightarrow A_{st} = 1305.18$

Assume, 20 mm ϕ

$n \times \frac{\pi}{4} \times (20)^2 = 1305.18$

$\Rightarrow n = \frac{1305.18 \times 4}{\pi \times (20)^2} = 4.15 \approx 4$



$\text{Spacing} = \frac{b - 2d'}{n-1}$

$= \frac{270 - 2 \times 30}{4 - 1}$

$= 70$ Ans

Dt. 18/03/24

Q. Design a rectangular beam which carries a maxm bending moment of 65 kN.mt. Using M_{20} concrete and Fe_{415} steel

Ans

Bending moment = 65 kN.mt.

Design moment (M_u) = 1.5 × 65

Given, M_{20}, Fe_{415} = 97.5 kN.m

= 97.5×10^6 N.m.

Assume, $b = \frac{d}{2}$

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

$\Rightarrow 97.5 \times 10^6 = 0.138 \times 20 \times \frac{d}{2} \times (d)^2$

$\Rightarrow d^3 = \frac{97.5 \times 10^6 \times 2}{0.138 \times 20}$

$\Rightarrow d = \sqrt[3]{\frac{97.5 \times 10^6 \times 2}{0.138 \times 20}}$

$= 413.40 \simeq 420$ mm.

$\therefore b = \frac{d}{2} = \frac{420}{2} = 210$ mm.

Assume, $d' = 30$ mm

$D = d + d'$

$= 420 + 30 = 450$ mm.

then,

$M_u = 0.87 f_y A_{st} d \left(\frac{1 - f_y A_{st}}{f_{ck} b d} \right)$

~~= 0.87 ×~~

$$\Rightarrow 97.5 \times 10^6 = 0.87 \times 415 \times A_{st} \times 420 \left(1 - \frac{415 \times A_{st}}{20 \times 210 \times 420}\right)$$

$$\Rightarrow 97.5 \times 10^6 = 151641\, A_{st} \left(1 - 2.35 \times 10^{-4} A_{st}\right)$$

$$\Rightarrow 97.5 \times 10^6 = 151641\, A_{st} - 35.63\, A_{st}^2$$

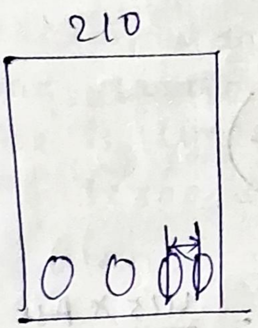
$$\Rightarrow 35.63\, A_{st}^2 - 151641\, A_{st} + 97.5 \times 10^6 = 0$$

$$\Rightarrow A_{st} = 789.37$$

Assume, 16 mm ϕ

$$n \times \frac{\pi}{4} \times (16)^2 = 789.37$$

$$\Rightarrow n = \frac{789.37 \times 4}{\pi \times (16)^2} = 3.92 \simeq 4$$

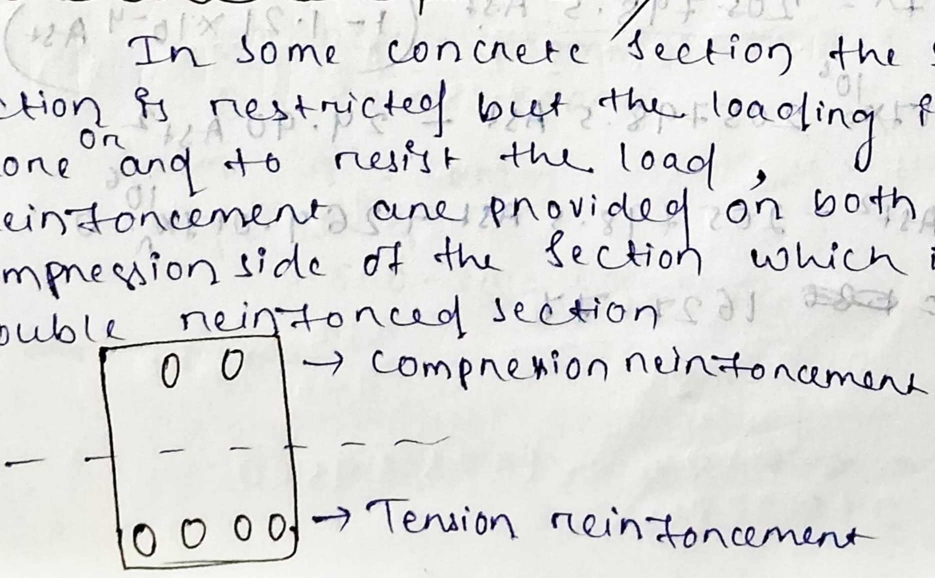


$$\text{spacing} = \frac{b - 2d'}{n-1} = \frac{210 - 2 \times 30}{4 - 1} = 50$$

Double Reinforced Section →

DL 22/03/24

In some concrete section the size of the section is restricted but the loading is high or more and to resist the load, Reinforcement are provided on both tension and compression side of the section which is called double reinforced section



Q. Determine the main tension reinforcement required for a rectangular beam of size ~~300mm~~ 300mm × 600mm. carrying a factored moment of ~~165~~ 170 KN-m. with concrete of grade M20 and steel Fe 415.

Ans. Given,

$b = 300 mm$

$D = 600 mm.$

Assume $d' = 30mm.$

$d = 600 - 30 = 570 mm.$

$Mu_{lim} = 0.138 f_{ck} b d^2$

$= 0.138 \times 20 \times 300 \times (570)^2$

$= 269017200$

$= 269.017 \times 10^6$

~~= 269.017~~

$Mu_{lim} = 0.87 f_y A_{st} d \left(1 - \frac{f_y A_{st}}{f_{ck} b d}\right)$

$\Rightarrow 269.017 \times 10^6 = 0.87 \times 415 \times A_{st} \times 570 \left(1 - \frac{415 \times A_{st}}{20 \times 300 \times 570}\right)$

$\Rightarrow 269.017 \times 10^6 = 205798.5 A_{st} (1 - 1.21 \times 10^{-4} A_{st})$

$\Rightarrow 269.017 \times 10^6 = 205798.5 A_{st} - 24.90 A_{st}^2$

$\Rightarrow 24.90 A_{st}^2 - 205798.5 A_{st} + 269.017 \times 10^6 = 0$

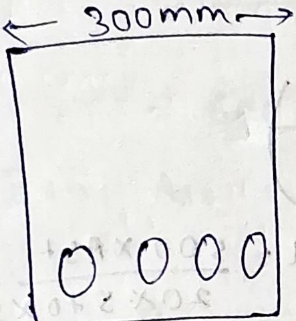
$\Rightarrow A_{st} = 1627.77$

Assume, 25 mm ϕ

$\Rightarrow n \times \frac{\pi}{4} \times (25)^2 = 1627.77$

$\Rightarrow n = \frac{1627.77 \times 4}{\pi \times (25)^2}$

$\Rightarrow n = 3.31 \simeq 4$



$\text{spacing} = \frac{b - 2d'}{n-1}$

$= \frac{300 - 2 \times 30}{4 - 1}$

$= 80$

(96 page)

Q. (previous ans) Design a simply supported rectangular beam in flexure. To resist a factored load of 90 kN/mt. over a clear span of 6 mt. and the size is limited to 30cm × 60 cm. Use M_{20} concrete and Fe500 steel. (10 Marks) Dt. 23/03/24

Ans

Given, $w = 90$ kN/mt.

$L = 6$mt.

$M_u = \frac{wl^2}{8} = \frac{90 \times (6)^2}{8} = 405$ kN.mt.

$b = 30$cm $= 300$mm

$D = 60$cm $= 600$mm.

Assume $d' = 30$mm

$d = D - d'$

$= 600 - 30 = 570$mm.

~~M_{20}, Fe500~~

M_{20}, Fe500

$M_{ulim} = 0.133 f_{ck} b d^2$

$= 0.133 \times 20 \times 300 \times (570)^2$

$= 259270200$

$= 259.27$ KN.m.

$= 259.27 \times 10^6$

$\frac{fy}{1.15}$

$M_{ulim} =$ ~~0.87 fck bd~~

$0.87 f_y A_{st} \, d \left(1 - \frac{f_y A_{st}}{f_{ck} b d}\right)$

$= 0.87 \times 500 \times A_{st} \times 570 \left(1 - \frac{500 \times A_{st}}{20 \times 570 \times 300}\right)$

$= 247950 A_{st} \left(1 - 1.46 \times 10^{-4} A_{st}\right)$

$\Rightarrow 259.27 \times 10^6 = 247950 A_{st} - 36.20 A_{st}^2$

$\Rightarrow 36.20 A_{st}^2 - 247950 A_{st} + 259.27 \times 10^6 = 0$

$\Rightarrow A_{st_1} = 1287.76$

then put the formula →

$f_{sc} = \frac{f_y}{1.15}$

IMP

$M_u - M_{ulim} = f_{sc} A_{sc} (d - d')$

$\Rightarrow 405 \times 10^6 - 259.27 \times 10^6 = \frac{f_y}{1.15} A_{sc} (570 - 30)$

$\Rightarrow 145730000 = \frac{500}{1.15} A_{sc} \times 540$

$\Rightarrow \frac{145730000}{A_{sc}} = \frac{500}{1.15} \times 540$

$\Rightarrow$ ~~Asc~~ $167589500 = 270000 A_{sc}$

$\Rightarrow Asc = \dfrac{167589500}{270000}$

$\Rightarrow Asc = 620.70$ (Area of compression reinforcement)

$Ast_2 = \dfrac{Asc\, f_{sc}}{0.87 f_y}$

$= \dfrac{620.70 \times \left(\dfrac{500}{1.15}\right)}{0.87 \times 500}$

$= 620.38$

Total $Ast = Ast_1 + Ast_2$

$= 1287.76 + 620.38$

$= 1908.14\ mm^2$

Assume, 25mm ϕ in tension for Ast

12mm ϕ in compression for Asc

For 25 mm ϕ

$\Rightarrow n \times \dfrac{\pi}{4} \times (25)^2 = 1908.14$

$\Rightarrow n = \dfrac{1908.14 \times 4}{\pi \times (25)^2} = 3.88 \simeq 4$

Spacing $= \dfrac{b - 2d'}{n-1}$

$= \dfrac{300 - 2 \times 30}{4-1}$

$= 80$ Ans

$1800 = 25mm$

$900 - 80 = 16\ mm$

For 16mm ϕ

$\Rightarrow n \times \dfrac{\pi}{4} \times (16)^2 =$ ~~800/1.15~~ 620.7

$\Rightarrow n \times \dfrac{\pi}{4} \times (16)^2 =$ ~~434.78~~ 620.7

$\Rightarrow n = \dfrac{\text{~~434.78~~ } 620.7 \times 4}{\pi \times (16)^2} =$ ~~3.84~~ $3.08 \simeq 3$

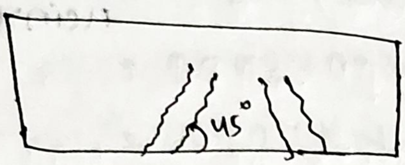
Spacing $= \dfrac{b - 2d'}{n-1}$

$= \dfrac{300 - 2 \times 30}{3-1}$

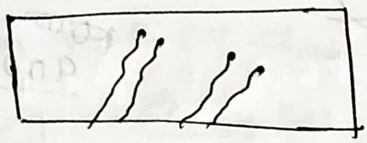
$= 120$ Ans

Shear Design

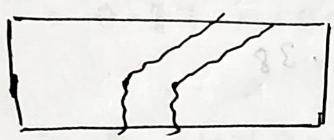
Dt. 04/04/24

① 

Web shear failure

② 

Flexural Tension failure.

③ 

Flexural compression shear failure

→ Bending in concrete beam is accompanied by shear which results in the shear failure of beams.

→ To resist the shear failures, stirrups are provided which is called shear reinforcement.

Design of shear reinforcement :→

① Nominal shear stress in beam

$$\tau_v = \frac{V_u}{bd}$$

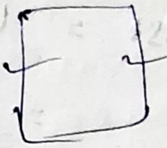
V_u = Design shear force
b = width of beam
d = depth of beam

Page - 73
Table - 19
Compare τ_v with τ_c →

(2) ~~Compare τ_v with~~ τ_c

If $(\tau_v < \tau_c)$

$$\frac{A_{sv}}{0.4 S_v} = \frac{0.4}{0.87 f_y}$$



2 legged stirrup

$A = 2 \times \frac{\pi}{4} \times \phi^2$

$A = n \times \frac{\pi}{4} \times \phi^2$

A_{sv} = Area of stirrup
S_v = spacing of stirrup

If $(\tau_v > \tau_c)$ → $V_{us} = V_u - \tau_c bd$

$$V_{us} = \frac{0.87 f_y A_{sv} d}{S_v}$$

(Q) A simply supported beam with clear span 6mt., width 400mm and effective depth 560mm. Carries a working load of 100kN/mt. It is reinforced with 4 bars of 25mm φ of grade Fe500. Design the shear reinforcement using M20 concrete?

Ans Given,
$l = 6$ mt.
Working load = 100 kN/m.
Design load = F. S.
$= 1.5 \times 100$
$= 150$ kN/mt.

Shear force $= V_u = \frac{wl}{2}$

$= \frac{150 \times 6}{2} = 450$ kN

b = 400mm.
d = 560mm.

$$\tau_v = \frac{V_u}{bd} = \frac{450 \times 10^3}{400 \times 560} = 2.00$$

$= 2.0$ N/mm²

$$\frac{100 A_{st}}{bd}$$

$$A_{st} = 4 \times \frac{\pi}{4} \times (25)^2$$

$$= 1963.49 \, mm^2$$

$$\frac{100 A_{st}}{bd} = \frac{100 \times 1963.49}{400 \times 560}$$

$$= 0.87$$

$\frac{100 A_{st}}{bd}$	τ_c
0.75	– 0.56
1.00	– 0.62

$d = D - d'$

$d + d' = 0$

$$\tau_c = 0.56 + \frac{0.62 - 0.56}{1 - 0.75} \times (0.87 - 0.75)$$

$$= 0.59$$

Here $\tau_v > \tau_c$

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

$$= 450 \times 10^3 - 0.59 \times 400 \times 560$$

$$= 317840 \, N$$

Assume,

2 legged 8mm stirrup

$$A_{sv} = 2 \times \frac{\pi}{4} \times (8)^2$$

$$= 100.53 \, mm^2$$

$$\Rightarrow V_{us} = \frac{0.87 f_y A_{sv} d}{S_v}$$

$$S_v = \frac{0.87 f_y A_{sv} d}{V_{us}}$$

$$= \frac{0.87 \times 500 \times 100.53 \times 560}{317840}$$

$$= 77.04 \approx 80\text{mm}.$$

Provide 2 legged 8mm Stirrup @ 80mm c/c.

Shear Design

(Q) A RCC beam of span 5mt. is 250mm width and 500mm effective depth. It has 4 bars of 22mm tensile reinforcement. The beam carries a load of 30KN/mt including its self weight. Design the beam of shear using M_{20} concrete and Fe415 steel?

Ans Given,

$L = 5mt.$

$b = 250mm$

$d = 500mm$

$n = 4$

~~Working load = $w = 30KN/mt$~~

Working load = 30KN/mt

Design load = F.V

= 1.5 × 30

= 45 KN/m.

~~Shear force = $V_u = \frac{WL}{2} = \frac{30 \times 5}{2} = \frac{150}{2} = 75KN$~~

Shear force = $V_u = \frac{WL}{2}$

$$= \frac{45 \times 5}{2} = \frac{225}{2} = 112.5 \text{ KN}$$

$b = 250\text{ mm}$

$d = 500\text{ mm}$

$$\tau_v = \frac{V_u}{bd} = \frac{112.5 \times 10^3}{250 \times 500} = 0.9 \text{ N/mm}^2$$

4 bars of 22 mm ϕ

$A_{st} = 4 \times \frac{\pi}{4} \times (22)^2$

$= 1520.53 mm^2$

$\frac{100 A_{st}}{bd}$

$= \frac{100 \times 1520.53}{250 \times 500}$

$= 1.21$

$\frac{100 A_{st}}{bd}$	τ_c
1.00	0.62
1.25	0.67

$\tau_c = 0.62 + \frac{0.67 - 0.62}{1.25 - 1} \times (1.21 - 1)$

$= 0.66$

~~Here $\tau_v < \tau_c$~~ Here $\tau_v > \tau_c$

~~$\frac{A_{sv}}{0.4 S_v} = \frac{0.4}{0.87 f_y}$~~

~~$\Rightarrow A_{sv} = 0.4$~~

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

$= 112.5 \times 10^3 - 0.66 \times 250 \times 500$

$= 30000$

Assume, 2 legged 8 mm stirrup

$A_{sv} = 2 \times \frac{\pi}{4} \times (8)^2$

$= 100.53 mm^2$

$$V_{us} = \frac{0.87 f_y A_{sv} d}{S_v}$$

$$\Rightarrow S_v = \frac{0.87 \times 415 \times 100.53 \times 500}{30000}$$

$= 604.93$ mm.

Max^m spacing $= ~~0.75 d~~$ $0.75 d$
450 mm.

$= 375$ mm

~~SLAB DESI~~
~~Development~~

Dt. 10/04/24

Development length and Anclonage :→

→ Development length.

To ensure proper bonding bet^n steel and concrete in RCC st. a certain length of the reinforcement is embedded in to the concrete, which is called development length.

This length is required to transfer the stress from steel to concrete.

The development length is given by

$$L_d = \frac{\phi \sigma_s}{4 \tau_{bd}}$$

where,

ϕ = diameter of bar

σ_s = stress in steel $\left(\frac{f_y}{1.15}\right)$

τ_{bd} = Design bond stress

Anchorage →

To hold the reinforcement in proper position the end of the reinforcement is bend in to a circular shape which is called anchorage.

→ The anchorage value is 4 times the diameter of bars for each 45° bending, which is a maxm of 16 times diameter of bars.

(Q) A steel bar of 10mm diameter of Fe415 grade is embedded in M20 concrete. calculate it's development length and anchorage value in tension and compression with a bend of 90°.

Ans $\phi = 10mm$.

Fe415, M20

For plain bars that table. either that case. 60% / 25%. 1.6 1.25

$\sigma_s = \frac{415}{1.15} = 360.8$ $\left(\sigma_s = \frac{f_y}{1.15}\right)$

$\tau_{bd} = 1.2 \times 1.6$
$= 1.92$

Tension →

$L_d = \frac{\phi \sigma_s}{4\tau_{bd}}$

$= \frac{10 \times 360.8}{4 \times 1.92} = 469.79mm.$

Compression →

$L_d = \frac{\phi \sigma_s}{4\tau_{bd}}$

$= \frac{10 \times 360.8}{4 \times 1.92 \times 1.25} = 375.83mm.$

$\theta = 90^\circ$

Anchorage value $= 2 \times 4\phi$

$= 2 \times 4 \times 10 = 80mm$.

Assignment

Q. Calculate the development length and anchorage value for a 16mm ϕ bar of grade Fe500, embedded in to a concrete of M_{25} both in tension and compression with a bend of 45°.

Ans $\phi = 16mm$

Fe500, M_{25}

$\sigma_s = \frac{500}{1.15} = 434.78$

$\tau_{bd} = 1.4 \times 1.6 = 2.24$

Grade of concrete.	Design bond stress τ_{bd}, N/mm²
M_{20}	1.2
M_{25}	1.4
M_{30}	1.5
M_{35}	1.7
M_{40}	1.9

Tension =

$L_d = \frac{\phi \sigma_s}{4 \tau_{bd}}$

$= \frac{16 \times 434.78}{4 \times 2.24}$

$= 776.39mm$.

Compression =

$L_d = \frac{\phi \sigma_s}{4 \tau_{bd}}$

$= \frac{16 \times 434.78}{4 \times 2.24 \times 1.25}$

$= 621.11 mm$.

$\theta = 45^\circ$

Anchorage value $= 2 \times 4\phi$

$= 2 \times 4 \times 16$

~~= 360~~ 128

SLAB DESIGN :→

Dt. 13/04/24

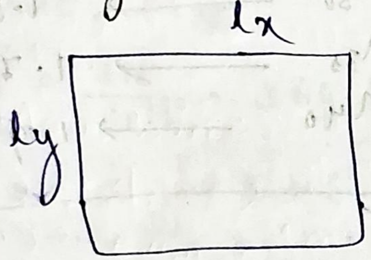
Slab is a plate element forming floors and roofs of a building carrying the distributed load.

Types of slab :→

Depending on the shape of the slab it is of different types →

1. Rectangular / square slab
2. Circular slab
3. Flat slab
4. Grid / Ribbed slab

(1) Rectangular slab :→



ly = Largest side length

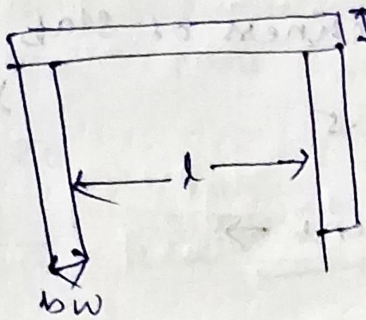
lx = Smallest side length

$\frac{l_y}{l_x} \leq 2$ This is two way slab

$\frac{l_y}{l_x} > 2$ This is one-way slab

(Imp)

Effective span (page no - 34)



where,
l = clean span
bw = support width
d = effective depth of slab

effective span = l + bw } which ever is less
l + d

Depth of slab

① For one way slab →
span to effective depth
→ Cantilever = $\frac{4d}{7}$
→ simply supported = 20
~~Cantilever =~~
→ Cantinuous = 26

② For two way slab → (page-39)
span to overall depth
simply supported slab = 35
continuous slab = 40

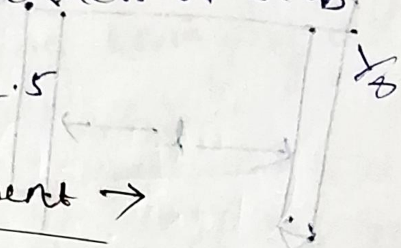
Min^m reinforcement ⇒ (48 P.g.)

✓ Grade of mild steel = Fe250
Min^m Ast = 0.15 % of cross-sectional area
Fe 415, Fe500, Fe 550
Min^m Ast = 0.12 % of cross-sectional area

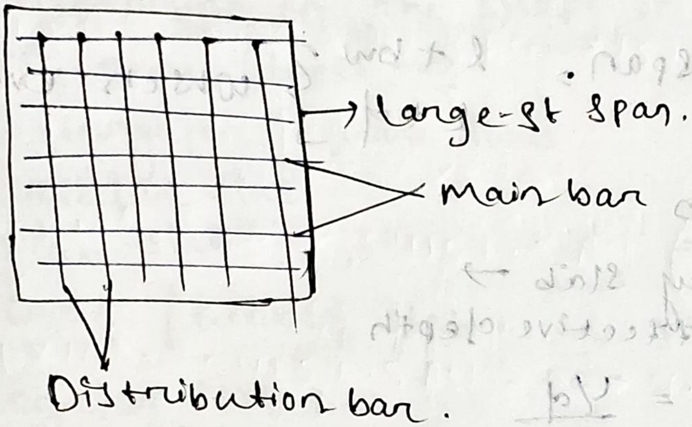
Maximum diameter → (48)

Man^m $\phi \ngtr \frac{1}{8} \times$ thickness of slab.

$\frac{1}{8} \times 100 = 12.5$



Spacing of reinforcement →



Slabs

(page no - 46)

Main bar
(i) 3 × d
(ii) 300 mm } smaller

Distribution bar
(i) 5 × d
(ii) 450 mm } smaller

Dt. 16/04/24

Q. Design a simply supported one way roof slap for a room of clear size 8m × 3.5m subjected to a loading of 5 KN/m², use M20 concrete and Fe415 steel.

Ans
8m × 3.5m
$w = 5$ KN/m²

Design load $= 1.5 \times 5$
$= 7.5$ KN/m²

given, M_{20}, Fe_{415}

For simply supported beam effective depth ratios for spans up to 10m = 20

$\therefore \frac{l}{d} = 20$ (l = which is less = 3.5 m = 3.5×10^3 mm)

$\Rightarrow d = \frac{l}{20} = \frac{3.5 \times 10^3}{20}$

$= 175$ (max^m d = 175 mm)

Assume, d = 150mm.

d' = 20mm.

D = d + d' = 170mm.

(1cum. concrete wt. = 25 kN/m3, we consider for 1m)

constant.

Dead load = (25) × 0.17 × (1)

= 4.25

170mm = 0.17m.

Total = 5 + 4.25

= 9.25

(Total load = Dead load + live load.)

Design = ~~9.25 × 1.5~~

9.25 × 1.5

= 13.875 kN/m.

For simply supported beam $M = \frac{wl^2}{8}$

$= \frac{13.875 \times (3.5)^2}{8}$

= 21.24 ~~N/mm2~~ kN.m

For Fe_{415} $M_u = 0.138 f_{ck} b d^2$ [1 m = 1000mm.]

$\Rightarrow 21.24 \times 10^6 = 0.138 \times 20 \times 1000 \times d^2$

$\Rightarrow d = \sqrt{\frac{21.24 \times 10^6}{0.138 \times 20 \times 1000}}$

= 87.72

Hence,

$d = 150mm$ is ok.

For single reinforcement:

$$M = 0.87 f_y A_{st} d \left(1 - \frac{f_y A_{st}}{f_{ck} b d}\right)$$

$$\Rightarrow 21.24 \times 10^6 = 0.87 \times 415 \times A_{st} \times 150 \left(1 - \frac{415 \times A_{st}}{20 \times 1000 \times 150}\right)$$

$$\Rightarrow 21.24 \times 10^6 = 54157.5 A_{st} \left(1 - 1.38 \times 10^{-4} A_{st}\right)$$

$$\Rightarrow 21.24 \times 10^6 = 54157.5 A_{st} - 7.47 A_{st}^2$$

$$\Rightarrow 7.47 A_{st}^2 - 54157.5 A_{st} + 21.24 \times 10^6 = 0$$

$$\Rightarrow A_{st} = 416.06 \; mm^2$$

Min^m A_{st} = 0.12% of cross-sectional area

$$= \frac{0.12}{100} \times 1000 \times 170$$

(170 → D)

$$= 204 \; mm^2$$

Assume, 10mm ϕ as main bar

$$A_{st} = n \times \frac{\pi}{4} \times (10)^2$$

$$\Rightarrow 416.06 = n \times \frac{\pi}{4} \times (10)^2$$

$$\Rightarrow n = \frac{416.06 \times 4}{\pi \times (10)^2} = 5.29 \simeq 5$$

Spacing = $\frac{b - d'}{n-1}$

$= \frac{1000 - 20}{5 - 1}$

$= 245 \text{ mm} \simeq 250 \text{ mm}$.

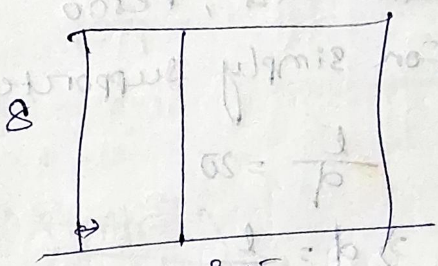
Provide 10mm and @ 250mm c/c. as main bar.

Assume, 8mm ϕ as distribution bar.

$A_{st} = n \times \frac{\pi}{4} \times (8)^2$

$\Rightarrow n = \frac{204 \times 4}{\pi \times (8)^2}$

$= 4.05 \simeq 4$



Spacing = $\frac{b - 2d'}{n-1}$

$= \frac{1000 - 20}{4 - 1}$

$= 326 \simeq 330 \text{ mm}$.

provide 8mm and @ 330mm c/c as distribution bar.

(Q) Design a simply supported one way slab for a room of size 3m x 7m. Subjected to a ~~Sta~~ live load of 4 kN/m2. Use M_{25} concrete and ~~Fe415~~ Fe500 steel.

Ans Given,

Size of room = 3m x 7m.

Live load w = 4 kN/m²

Design load = 4 x 1.5

= 6 kN/m²

~~Give~~ M_{25}, Fe500

For simply supported beam

$\frac{l}{d} = 20$

$\Rightarrow d = \frac{l}{20}$

$\Rightarrow d = \frac{3 \times 10^3}{20} = 150mm.$

Assume, d = ~~150mm~~ 145 mm.

d' = 20mm

D = d + d' = ~~150~~ 145 + 20 = ~~170mm~~ 165mm.

Dead load = 25 x 0.17 x 1

= 4.25

Total load = 4 + 4.25

= 8.25

Design load = W.γ.

= 8.25 x 1.5

= 12.375 kN/mt.

for simply supported beam $M = \frac{wl^2}{8}$

$= \frac{12.375 \times (3)^2}{8}$

for Fe500 $= 13.92$ kN.m

$M = 0.133 f_{ck} b d^2$

$\Rightarrow 13.92 \times 10^6 = 0.133 \times 25 \times 1000 \times d^2$

$\Rightarrow d = \sqrt{\frac{13.92 \times 10^6}{0.133 \times 25 \times 1000}}$

$\Rightarrow d = 64.70$

Hence, $d = 145$ mm is ok

for single reinforcement.

$M = 0.87 f_y A_{st} d \left(1 - \frac{f_y A_{st}}{f_{ck} b d}\right)$

$\Rightarrow 13.92 \times 10^6 = 0.87 \times 500 \times A_{st} \times 145 \left(1 - \frac{500 \times A_{st}}{25 \times 1000 \times 145}\right)$

$\Rightarrow 13.92 \times 10^6 = 63075 A_{st} \left(1 - 1.37 \times 10^{-4} A_{st}\right)$

$\Rightarrow 13.92 \times 10^6 = 63075 A_{st} - 8.64 A_{st}^2$

$\Rightarrow 8.64 A_{st}^2 - 63075 A_{st} + 13.92 \times 10^6 = 0$

$\Rightarrow A_{st} = 227.79 mm^2$

Min^m $A_{st} = 0.12\%$ of A_{st}

$= \frac{0.12}{100} \times 1000 \times 165$

$= 198 mm^2$

Assume, 8 mm ϕ as main bar.

$A_{st} = n \times \frac{\pi}{4} \times (8)^2$

$\Rightarrow 227.79 = n \times \frac{\pi}{4} \times (8)^2$

$\Rightarrow n = \frac{227.79 \times 4}{\pi \times (8)^2}$

$= 4.53 \simeq 4$

Spacing $= \frac{b - d'}{n-1}$

$= \frac{1000 - 20}{4-1}$

$= 326.66 \text{ mm} \simeq 326 \text{ mm}$.

provide 8mm ϕ and @ 326 c/c as main bar.

Assume, 7 mm ϕ as distribution bar

$A_{st} = n \times \frac{\pi}{4} \times (7)^2$

$\Rightarrow 198 = n \times \frac{\pi}{4} \times (7)^2$

$\Rightarrow n = \frac{198 \times 4}{\pi \times (7)^2} = 5.14 \simeq 5$

Spacing $= \frac{b - d'}{n-1}$

$= \frac{1000 - 20}{5-1}$

$= 245 \text{ mm}$.

provide 7mm and @ 245 c/c as distribution bar.

Compression Member :→

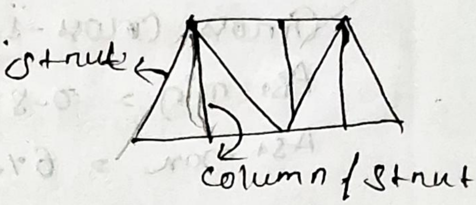
Dt-20/04/24

→ In ~~civil~~ a structure the path which takes the compression load is known as a compression member.

→ It is otherwise called column or strut.

→ Column always be straight.

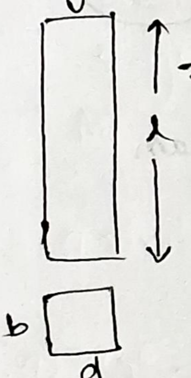
→ But the strut either straight or inclined.



→ Column is of 2 types →

① Short column

② long column



Slenderness ratio

$\frac{l}{b}$ or $\frac{l}{d}$ (page-41)

The ratio of length to least lateral dimension of column is called slenderness ratio.

★ (2 marks) When the slenderness ratio is less than 12 it is called short column.

And when it is greater than 12 it is called long or slender column.

Limit state of collapse. Assumption (page. No. 70)
compression

Minimum Eccentricity → (P.g. 42)

$$e_{min} = \frac{l}{500} + \frac{b \text{ or } d}{30} \nless 20mm.$$

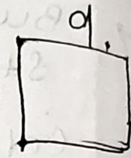
Min^m reinforcement in column :→ (P.g. 48)

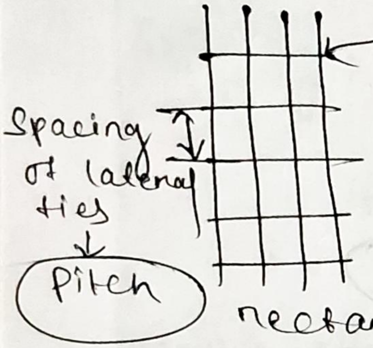
Gross cross-sectional area (Ag) = b×d

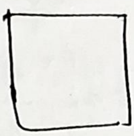
A_{st} min = 0.8% of Ag

A_{st} max = 6% of Ag

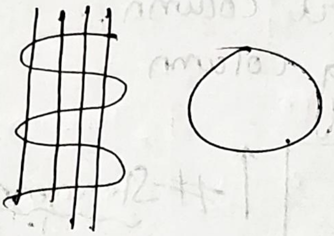
| 0.8 ⟺ 6 |







rectangular beam.



Circular beam

Pitch

- The max^m pitch should be least of
  - (i) b or d
  - (ii) 16 φ
  - (iii) 300mm

Diameter

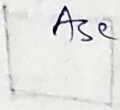
- (i) $\frac{1}{4}\phi$
- (ii) 6 mm.

Column Design

Pg-71, cl-39.3

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

A_c = Area of concrete



A_{sc} = Area of steel

Q - A column of size 30 cm x 30 cm is Reinforced with 6 nos 16mm ϕ. Find the safe axial load the column can carry using M20 & fe 415.

Soln -

30 cm x 30 cm - 300 mm x 300 mm

$A_g = 300 \times 300 = 90000 \ mm^2$

$A_{sc} = 6 \times \frac{\pi}{4} \times 16^2 = 1206.37 \ mm^2$

$A_c = A_g - A_{sc} = 90000 - 1206.37$

~~= 89963.~~

= 88793.63

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

$= 0.4 \times 20 \times 88793.63 + 0.67 \times 415 \times 1206.37$

= 1045780.219 N

= 1045.78 kN

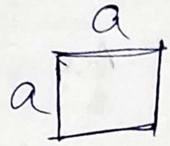
Dt. 26/04/24

Design of column

Design a RCC column to resist axial factored load of 1800 kN. Given column length 3m with both end fixed using M20 concrete & fe415 steel.

Soln –

$P_u = 1800$ kN



$L = 3$ m

M20, fe415

Assume square column

$A_g = a^2 / \frac{\pi}{4} d^2 / b \times d$

$A_{sc} = \frac{0.8}{100} A_g = 0.008 A_g$

$A_c = A_g - A_{sc}$

$= A_g - 0.008 A_g$

$= A_g (1 - 0.008) = 0.992 A_g$

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

$\Rightarrow 1800 \times 10^3 = 0.4 \times 20 \times 0.992 A_g + 0.67 \times 415 \times 0.008 A_g$

$\Rightarrow 1800 \times 10^3 = 10.16 A_g$

$\Rightarrow A_g = \frac{1800 \times 10^3}{10.16}$

$= 177165.35$

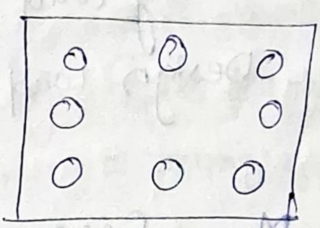
$a^2 = 177165.35$

$\Rightarrow a = \sqrt{177165.35}$

$= 420.91$

$\simeq 430$ mm

430 × 430 mm



$A_{sc} = 0.008\, A_g$

$= 0.008 \times 430 \times 430$

$= 1479.2$ mm²

Assume 16 mm ϕ

$n \times \frac{\pi}{4} \times 16^2 = 1479.2$

$\Rightarrow n = \frac{1479.2 \times 4}{\pi \times 16^2} = 7.35$

$\simeq 8$

Assume lateral ties

i) $\frac{1}{4} \times 16 = 4$ mm

ii) 6 mm

Assume 6 mm ϕ

Pitch – i) 430

ii) 16 × 16 = 256

iii) 300 mm

So Pitch = 260 mm

Q - Design a short circular column to carry a working load of 1000 kN using M25 concrete & Fe500 steel.

Ans Working load = 1000 kN

Design load = 1.5 × 1000

= 1500 kN

M_{25}, Fe500

In circular beam

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

$A_{sc} = \frac{0.8}{100} \times A_g$.

$= 0.008 A_g$.

$A_c = A_g - A_{sc}$

$= A_g - 0.008 A_g$

$= A_g (1 - 0.008)$

$= 0.992 A_g$.

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

~~= 0.4 × 20~~

⇒ $1500 \times 10^3 = 0.4 \times 25 \times 0.992 + 0.67 \times 500 \times 0.008 A_g$

⇒ $1500 \times 10^3 = 12.6 A_g$

⇒ $A_g = \frac{1500 \times 10^3}{12.6} = 119047.61$

$\frac{\pi}{4} \times (d)^2 = 119047.61$

$\Rightarrow d^2 = \frac{119047.61 \times 4}{\pi}$

$\Rightarrow d = \sqrt{\frac{119047.61 \times 4}{\pi}}$

$\Rightarrow d = 389.32 \simeq 390 \text{ mm}$. $A_g = \frac{\pi}{4} \times (309)^2$

$= 74990.60$

~~$\Rightarrow$~~ $A_{sc} = 0.008 A_g$

$= 0.008 \times 74990.60$

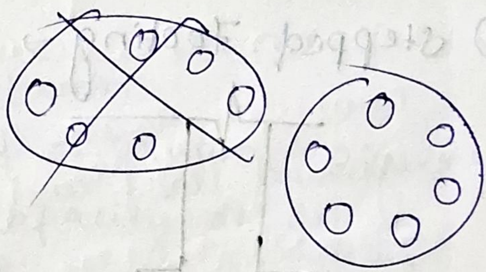
$= 599.92 \text{ mm}^2$

Assume 12mm ϕ

$\Rightarrow n \times \frac{\pi}{4} \times (12)^2 = 599.92$

$\Rightarrow n = \frac{599.92 \times 4}{\pi \times (12)^2}$

$= 5.30 \simeq 6$



Assume, lateral ties

① $\frac{1}{4} \times 12 = 3 \text{ mm}$

② 6mm

Assume 6mm ϕ

pitch = ① 390

② $16 \times 12 = 192$

③ 300mm

So pitch = ~~195mm~~

200mm

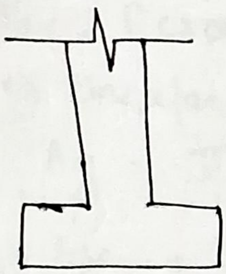
Footing Design

Dt. 27/04/24

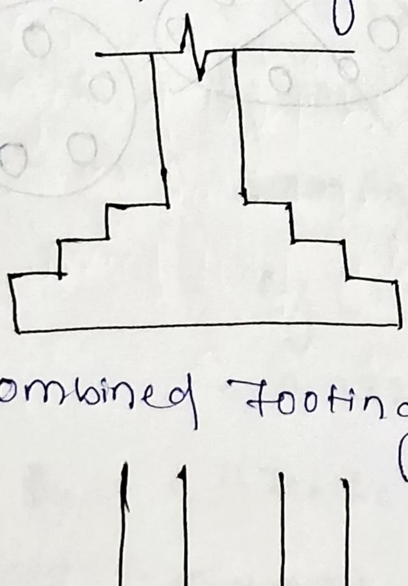
→ **Footing** → A spread constructed in brick work on concrete under the base of a wall of column for the purpose of distributing the load over a larger area is called Footing.

Types of Footing →

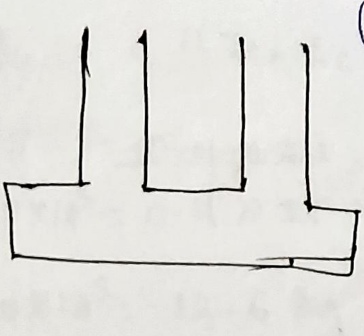
① Isolated Footing →



② Stepped Footing →



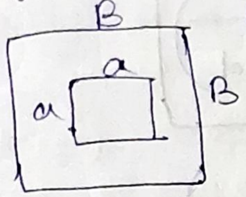
③ Combined Footing →



two column single footing

Design of isolated column footing →

(i) For footing the minimum cover is 50mm.



(ii) For column footing the maxm bending moment occurs at the face of the column.

$$M = q_0 \times B \times \left(\frac{B-a}{2}\right)^2 \times \frac{1}{2}$$

where,

q_0 = net upward pressure from soil

(iii) Area of footing required

$$A = \frac{W + W_1}{P_0}$$

where, W = Load of column

W_1 = Dead load of column (10% of W)

P_0 = Bearing capacity of soil

(iv) For sample footing

$B = \sqrt{A}$ (square)

$L \times B = A$ (Rectangular)

$\frac{\pi}{4} \times D^2 = A$ (circular)

(v) Maxm upward pressure from soil

$$q_0 = \frac{W \times 1.5}{\text{Area of footing provided}}$$

(vi) For depth of footing.

$M = 0.138 f_{ck} b d^2$ (Fe415)

$M = 0.133 f_{ck} b d^2$ (Fe500)

d = depth of footing

(7) for reinforcement

$$M = 0.87 f_y A_{st} d \left(1 - \frac{f_y A_{st}}{f_{ck} b d}\right)$$

find A_{st}

(8) Shear check

$$V_u = q_o \times B \times \left(\frac{B-a}{2} - d\right)$$

$$\tau_v = \frac{V_u}{bd} \ngtr \tau_c$$

τ_c table 19 pg 73

Q Design a square spread footing to carry a column load of 1400KN from a 400mm square column. The bearing capacity of soil 100 KN/m² consider base of footing 1m. below the ground level and the unit weight of earth is 20 KN/m³. Use M_{25} concrete and Fe415 steel.

Ans Axial load = 1400 KN

(Q) Design a square footing to carrying the column load of 1400KN from a 400 mm square column consider the bearing capacity of soil 100 KN/m², Unit wt. of soil is 20KN/m³ and the footing is 1mt below the ground level. Use M_{25} concrete and Fe_{415} steel.

Ans Given,

Axial load = 1400KN

Dead load = 10 % of axial load

$= \frac{10}{100} \times 1400$

= 140KN

Wt. of soil = 20KN/m³

below gL = 1mt

= 20 × 1 × 1 × 1

= 20 KN

Total load = 1400 + 140 + 20

= 1560KN

bearing capacity of soil (P_o) = 100KN/m²

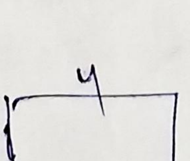
Area of footing required $A = \frac{\text{Total load}}{P_o}$

$= \frac{1560}{100}$

= 15.6 m²

For square footing $B = \sqrt{A} = \sqrt{15.6}$

= 3.94m. ≈ 4m.



Net upword pressure from soil

$$q_0 = \frac{W \times 1.5}{\text{Area of footing}}$$

$$= \frac{1400 \times 1.5}{4 \times 4}$$

$$= 131.25\ kN/m^2$$

M_{25}, Fe415

$$M_u = q_0 \times B \times \left(\frac{B-a}{2}\right)^2 \times \frac{1}{2} \quad (a = \text{size of column})$$

$$= 131.25 \times 4 \times \left(\frac{4-0.4}{2}\right)^2 \times \frac{1}{2}$$

$$= 850.5\ kN \cdot m.$$

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

$$850.5 \times 10^6 = 0.138 \times 25 \times 4000 \times d^2$$

$$\Rightarrow d^2 = \frac{850.5 \times 10^6}{0.138 \times 25 \times 4000}$$

$$\Rightarrow d = \sqrt{\frac{850.5 \times 10^6}{0.138 \times 25 \times 4000}}$$

$$\Rightarrow d = 248.325 \approx 250\ mm.$$

$$M_u = 0.87 f_y A_{st}\, d \left(1 - \frac{f_y A_{st}}{f_{ck} b d}\right)$$

$$\Rightarrow 850.5 \times 10^6 = 0.87 \times 415 \times A_{st} \times 250 \left(1 - \frac{415 A_{st}}{25 \times 4000 \times 250}\right)$$

$$\Rightarrow 850.5 \times 10^6 = 90262.5 A_{st} \left(1 - 1.66 \times 10^{-5} A_{st}\right)$$

$$\Rightarrow 850.5 \times 10^6 = 90262.5 A_{st} - 1.498 A_{st}^2$$

$$\Rightarrow 1.498 A_{st}^2 - 90262.5 A_{st} + 850.5 \times 10^6 = 0$$

$$\Rightarrow A_{st} = 11690.76\ mm^2$$

Assume, 20mm

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

$\Rightarrow 11690.76 = n \times \frac{\pi}{4} \times (20)^2$

$\Rightarrow n = \frac{11690.76 \times 4}{\pi \times (20)^2}$

$= 37.21 \simeq 37$

$\text{Spacing} = \frac{4000 - 2 \times 50}{37 - 1}$

$= \frac{4000 - 100}{36}$

$= \frac{3900}{36} = 108.3\overline{3} \simeq 110 \text{mm}$

∴ Provide 20mm and @ 110mm c/c.