

UNIT - 01

Compressive load
direct stress

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Reinforcement :-

Steel as reinforcement

In reinforced concrete, concrete being weak in tension, steel bars are used to carry the tension. Steel bars are also used to carry compression in beams and columns. For any material to be used as reinforcement for concrete it should possess the following properties -

- i) It should possess high tension strength.
- ii) It should be able to develop a good bond with concrete.
- iii) It should possess a high modulus of elasticity.
- iv) It should have the same temperature coefficient of expansion and contraction as concrete to avoid the development of thermal stress.
- v) It should be easily available.

$$\text{stress} = \frac{\text{load}}{\text{Area}} \quad \text{N/mm}^2$$

$$\text{strain} = \frac{\text{Deformation}}{\text{original length}}$$

$$\text{modulus of elasticity} = \frac{\text{stress}}{\text{strain}}$$

Many materials other than steel like asbestos, Glass, bamboo etc. were tried on experimental as reinforcement but were found to fail. Steel is a material which satisfy all the above requirement and is successfully used as reinforcement.

Types of reinforcement / steel.

i) Mild steel :- Mild steel have been used widely as reinforcement in construction industry. The yield strength of mild steel is 250 N/mm². Among all the kinds of steel mild steel is the most ductile.

Mild steel when used as reinforcement can yield on over loading. During yielding extensive cracking in concrete take place before it fails.

ii) Cold twisted deformed bars

High yield strength deformed steel bars. Based on experiments and prevailing practices in foreign country.

production of high strength ribbed bars was started. It was noticed that if a mild steel bar is strained beyond yield point by twisting and twisting and then unloaded the yield plateau is eliminated and a new stress-strain curve is obtained. As the high yield strength does not possess the definite yield point 0.2% proof stress is used as a yield stress.

Fe-415, Fe-500, Fe-550,

Advantages:-

- i) Because of high yield strength the mass of steel required is reduced.
- ii) Twisted bars have better bond with concrete than mild steel.
- iii) Cold working makes bars uniform by hardening the softer parts of mild steel.
- iv) As the consumption of this steel as compared to mild steel is less it leads to saving of total steel.

(ii) TMT Bars:- The TMT bars are manufactured by subjecting the hot rolled mild steel bars to a controlled

Cooling process which converts the outer surface of the bar into hardened structure. This cooling allows the hot inner core to soften the outer surface & through thermal exchange. This bars possess definite yield point and high bond strength. Due to higher ductility and toughness, these are used in earth quake prone areas.

Fe - 400, Fe - 500, Fe - 550

IV Corrosion Resistant Steel:-

Corrosion resistant steel has been developed and is being used in aggressive environments, marine structure etc.

These steel have the same usual grades Fe - 415, Fe 500 & Fe - 550. (i)

They are coated with corrosion resistant element. (ii)

* Strength of concrete

M5	-	up to M20	-	ordinary concrete
M25	-	M60	-	Standard concrete
M65	-	M above	-	High strength concrete

NOTE = M-20 Grade for Normal RCC

In See Condition M-20 for Concrete & M-30 for RCC

F_{ck} - characteristic strength of concrete

F_y = yield strength of steel

designing for bridges, dams, water tanks

1 # IS 450 - 1957 (working stress method)

- ⇒ Permissible stress = yield stress / FOS
- Economic condition is high
- Serviceability is high

2 # IS - 450 - 1964 (Ultimate load strength) method

- Permissible load is equal to ultimate load
- Economic condition is high
- Serviceability is low

4 # IS 450 - 2000 Limit stress method

Economical balanced
 &
 Serviceability

Shrinkage = allow 0.0003%

Bulking

Cement = $\pm 2\%$ tolerance
 other = $\pm 3\%$ tolerance

(★) Modular Ratio

$$M = \frac{280}{35} = 8$$

Grade

Modular Ratio

M - 15

19

M - 25

11

M - 30

9

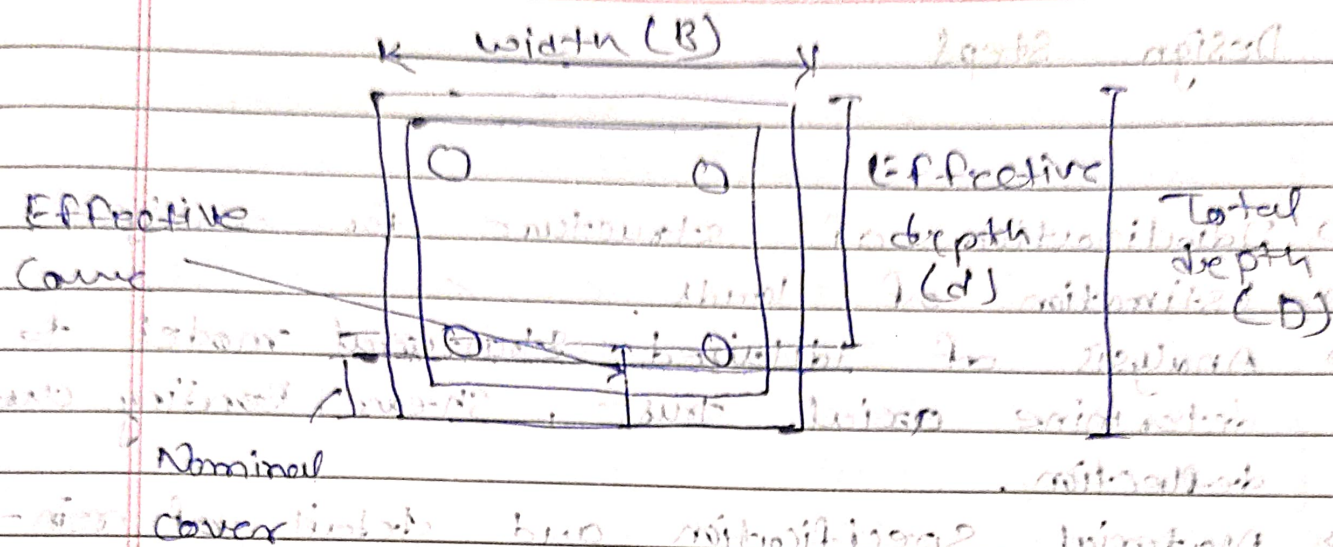
M - 35

8

M - 40

9

★ Nominal ^{Cover} Curve & ^{Cover} Effective Curve



$$\text{Total depth} = \text{Effective depth} + \text{Effective Cover}$$

Effective Cover:- Cover from outer fiber to bottom of concrete to the center of main reinforcement.

Nominal Cover:- It is the design depth provided to all steel reinforcement including stirrups.

Nominal cover for

Mild Exposure Condition

Slab $\geq 20 \text{ mm}$

Beam $\geq 25 \text{ mm}$

Column $\geq 40 \text{ mm}$

Foundation $\geq 50 \text{ mm}$

Design Steps

- Idealization of structure for analysis.
- Estimation of loads.
- Analysis of idealized structured model to determine axial, twist, shear, Bending and deflection.
- Material Specification and detail of reinforcement.
- Detailed drawing and schedule of reinforcement.

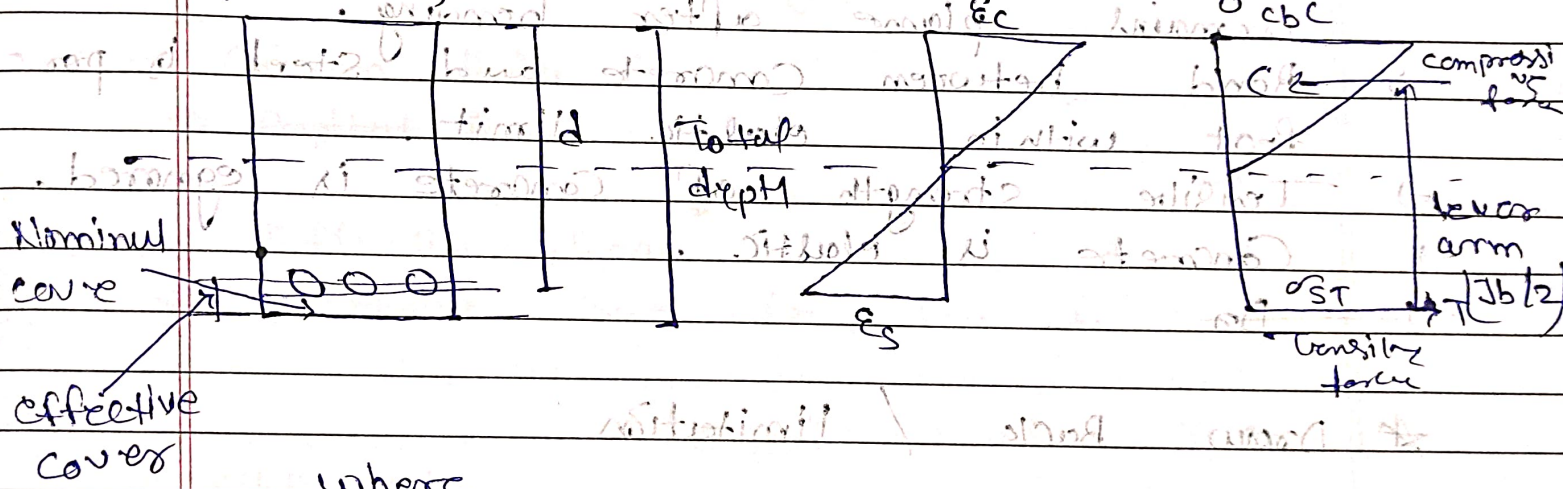
★ Working Stress Method:-

- i) Traditional method of designing
- ii) It is assumed that concrete is elastic
- iii) Steel and concrete together behaves elastically
- iv) The section are designed assuming the materials obey Hooke's law.
- v) The basis of this method is that the permissible stress for concrete & steel are not exceeded in any worst combination of working load.

→ Permissible stresses in concrete -

	Tension		Compression	
	Direct	Bending	Direct	Bending
M 15	2.0	2.7	4	5
M 20	2.8	3.13	5	7
M 25	3.2	3.5	6	8.5
M 30	3.6	3.83	8	10
M 35	4.0	4.14	9	11.5
M 40	4.4	4.43	10	13.5

width (b)



b = width of section

D = Total depth of section

d = Effective depth of section

A_{st} = Area of steel in tension

σ_c = Stress in concrete due to bending in compression, or permissible compressive stress in concrete.

σ_{st} = Permissible tensile stress in steel

C = total force in compression

T = total force in tension

$Jd/2$ = lever arm

Lever arm: It is defined as the distance between the point of application of force of compression and force of tension.

Assumption in LSM

→ A section which is plane before bending remains plane after bending.

→ Bond between concrete and steel is perfect within elastic limit.

→ Tensile strength of concrete is ignored.

→ Concrete is elastic.

→ Do

★ Draw Back / Limitation

→ Concrete is not elastic.

→ Difficult to account for shrinkage and creep in LSM.

★ Total load

Total load = load in concrete + load in steel

if two more $\sigma_{cbc} \times A_c + \sigma_{st} \times A_{st}$ (ii) $\sigma_{st} = m \sigma_{cbc}$

$$\left[\sigma_{st} = m \sigma_{cbc} \right]$$

$$= \sigma_{cbc} \times A_c + m \sigma_{cbc} \times A_{st}$$

$$\left[P = \sigma_{cbc} (A_c + m A_{st}) \right] \quad \text{--- (iii)}$$

★ Analysis of singly reinforced section

→ Given data

→ Effective span

→ Effective depth

→ Effective cover, A_{st} , F_{ck} , f_y

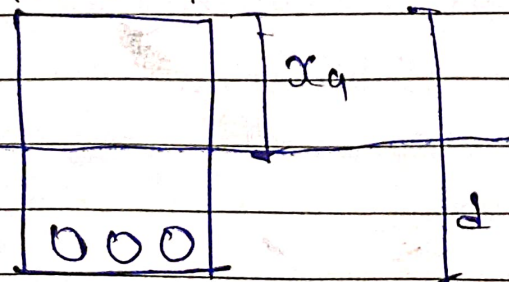
→ Effective cover, A_{st} , F_{ck} , f_y

★ STEP - 01

i) Actual depth of neutral axis (x_u)

Bending

$\leftarrow b \rightarrow$



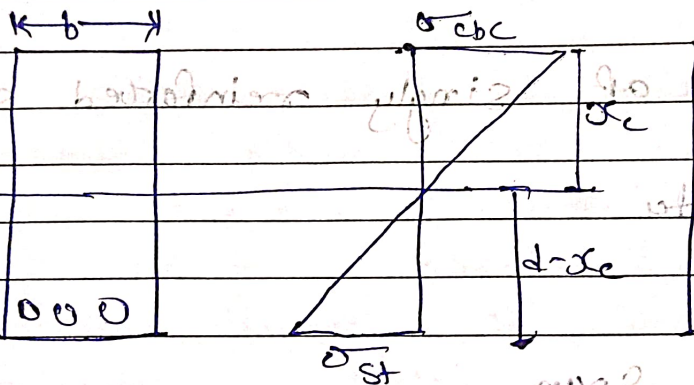
Bending moment in compression Bending moment in tension

$$\frac{(B \times x_c) \times x_c}{2} = m A_{st} (d - x_c)$$

for x_c

Step - 02

ii) Critical depth of Neutral axis



$$\frac{\sigma_{cbc}}{x_c} = \frac{\sigma_{st}}{m(d - x_c)}$$

$$\sigma_{st} = m \sigma_{cbc}$$

$$\sigma_{cbc} = \frac{\sigma_{st}}{m}$$

$$\frac{\sigma_{cbc}}{x_c} = \frac{\sigma_{st}}{m(d - x_c)}$$

$$\frac{m \sigma_{cbc}}{x_c} = \frac{\sigma_{st}}{d - x_c}$$

$$\frac{m \sigma_{cbc}}{\sigma_{st}} = \frac{x_c}{d - x_c}$$

$$\cancel{\sigma_{ce}} = \cancel{\frac{m \sigma_{cbc}}{\sigma_{st}}} (\cancel{d} - \cancel{x_c}) \quad (7)$$

$$\cancel{\sigma_{ce}} = \frac{\cancel{d} m \cancel{\sigma_{cbc}} - \cancel{x_c} m \cancel{\sigma_{cbc}}}{\cancel{\sigma_{st}}} \quad (8)$$

$$\frac{m \sigma_{cbc}}{\sigma_{st}} = \frac{\sigma_{ce}}{d} - \frac{x_c}{d} \quad (9)$$

$$\frac{m \sigma_{cbc}}{\sigma_{st}} = \frac{\sigma_{ce}}{d} - 1 \quad (10)$$

$$1 + \frac{m \sigma_{cbc}}{\sigma_{st}} = \frac{\sigma_{ce}}{d} \quad (11)$$

$$\frac{\sigma_{st} + m \sigma_{cbc}}{\sigma_{st}} = \frac{\sigma_{ce}}{d} \quad (12)$$

$$d \left[\frac{\sigma_{st} + m \sigma_{cbc}}{\sigma_{st}} \right] = \sigma_{ce} \quad (13)$$

Step - 03

iii) Comparison between actual neutral axis and critical neutral axis.

000

$\frac{\sigma_c}{E_c}$ - over
 $\frac{\sigma_s}{E_s}$ - under

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- (both)
- ① $x_u \geq x_c$ Balanced
 - ② $x_u < x_c$ Under reinforced
 - ③ $x_u > x_c$ Over reinforced

Step-04

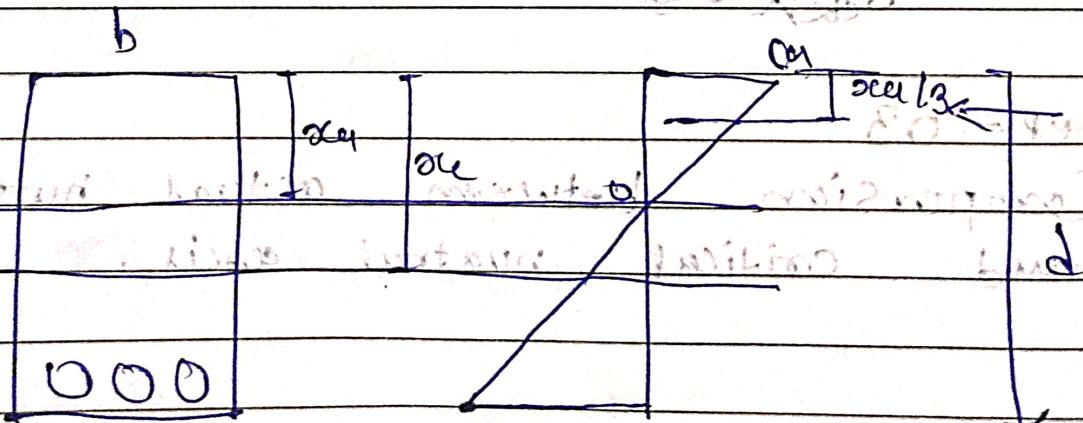
Moment of resistance :- It is the maximum capacity of the section to the maximum bending moment at which either one material fails or both material fails.

Case-I For Under reinforced section

$(M_R)_{Comp} = \text{Compressive force} \times \text{lever arm}$

$\sigma = \frac{P}{A}$
 $(M_R)_{Compress} = \text{Compressive stress} \times \text{lever arm}$
 $P = \sigma \times A$
 Compressive Area

$$(M_R)_{Compress} = \frac{(m + c)}{2} \times (b \times x_u) \times \left(d - \frac{x_u}{3} \right)$$



Case-I

Tensile force $\times$ (Lever arm)

$$(MOR)_{st} = \frac{\sigma_{st}}{m} \times m A_{st} \left[d - \frac{\alpha_g}{3} \right]$$

Case-II

Balanced

Section

$$(MOR)_c = b \times \alpha_c \left[\frac{\sigma_{bc} + 0}{2} \right] \times \left[d - \frac{\alpha_c}{3} \right]$$

$$(MOR)_t = \frac{\sigma_{st}}{m} \times m A_{st} \left[d - \frac{\alpha_c}{3} \right]$$

Case-III

over reinforced Section

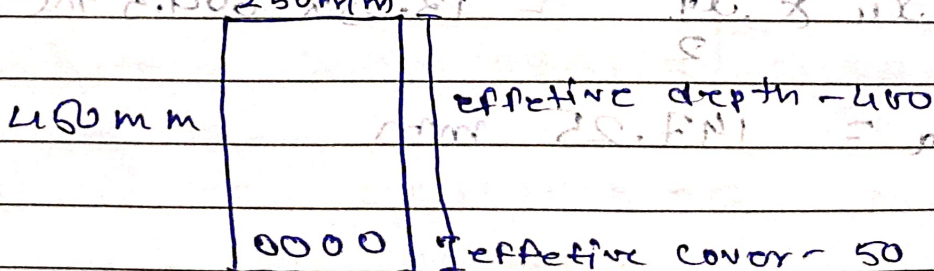
$$(MOR)_{crl} = b \times \alpha_c \left[\frac{\sigma_{bc} + 0}{2} \right] \left[d - \frac{\alpha_g}{3} \right]$$

Q1

A beam has overall dimension of 250 x 450 mm² and effective cover of 50 mm, 4 bars of 16 mm dia are used as tension reinforcement with Fe415 steel and M20 grade concrete. Find α_c , α_g , Type of section and moment of resistance.

Sol

given data:-



4 bars - 16 mm dia

$$[\text{ex. b}] \quad \text{width} = 250$$

$$\text{effective depth} = 400$$

4 bars of 16 mm dia

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

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

$$A_{st} = 804.57 \text{ mm}^2$$

grade of Steel = Fe 415

$$\sigma_{bc} = 230 \text{ N/mm}^2$$

Concrete = M-20

$$\left[\text{ex. b} \right] \left[\sigma_{bc} = 7 \text{ N/mm}^2 \right]$$

$$\text{modular ratio (m)} = \frac{230}{7}$$

$$3 \sigma_{bc}$$

$$13.33$$

$$3 \sigma_{bc}$$

$$13.33$$

i) Actual depth of Neutral Axis (x_a)

$$\frac{(B \times x_a) \times x_a}{2} = m A_{st} (d - x_a)$$

$$250 \times x_a \times \frac{x_a}{2} = 13.33 \times 804.57 \times (400 - x_a)$$

$$x_a = 147.25 \text{ mm}$$

ii) Critical depth of neutral axis

$$x_c = 400 \times \left[\frac{13.33 \times 7}{13.33 \times 7 + 230} \right]$$

$$x_c = 115.44 \text{ mm}$$

iii) Comparison between x_a & x_c

$$x_a = 147.25 \text{ mm}$$

$$x_c = 115.44 \text{ mm}$$

$$147.25 > 115.44$$

Over reinforced section

iv) Moment capacity Resistance

$$(M_{op})_c = b \times x_a \times \left[\frac{\sigma_{cbc} + 0}{2} \right] \times \left[\frac{d - x_a}{3} \right]$$

$$(M_{op})_c = 250 \times 147.25 \times \left[\frac{7 + 0}{2} \right] \times \left[\frac{400 - 147.25}{3} \right]$$

$$(M_{op})_c = 45213419.27 \text{ N mm}^2$$

$$= 45 \times 10^7$$

$$45.213$$

$$\text{KN m}^2$$

Notation for grade of steel

Fe 250 $\sigma_{yk} = 250 \text{ N/mm}^2$

Fe 415 $\sigma_{yk} = 415 \text{ N/mm}^2$

Fe 500 $\sigma_{yk} = 500 \text{ N/mm}^2$

Q:-

$b = 400$

effective cover 50mm

4-16mm

4-16mm

Solution

width = 400 mm

effective depth = 650 mm

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

$$A_{st} = 804.24 \text{ mm}^2$$

$\sigma_{bc} = 250 \text{ N/mm}^2$

$\sigma_{st} = 230 \text{ N/mm}^2$

$m = 13.33$

Brass

$m = 13.33$

i) Actual depth of neutral axis (mm) (ii)

$$(b \times x_a) \times x_g = \text{mast} \times (d \times x_a)$$

$$152.881 - 0.55 \times 1000^2 \times 0.85 = 1000$$

$$(2000 \times x_a \times) \frac{x_g}{2} = 13.33 \times 804.24 \times (650 \times x_a)$$

$$\text{Actual depth of neutral axis} = 1000 \text{ mm}$$

Actual depth of

ii) Critical depth of —

$$x_c = d \times \left[\frac{m \times 0.68 + 0}{m \times 0.68 + 0.85} \right]$$

Actual depth of neutral axis

$$x_c = 650 \times \left[\frac{13.33 \times 7}{13.33 \times 7 + 280} \right]$$

$$x_c = 197.59 \text{ mm}$$

Comparison between actual depth of neutral axis and critical depth of neutral axis

Since the actual depth of neutral axis is greater than the critical depth of neutral axis, the beam is under reinforced. Hence the beam will be safe. The actual depth of neutral axis is 1000 mm and the critical depth of neutral axis is 197.59 mm. Hence the beam is under reinforced.

$$ii) (MOR)_T = \frac{1081}{\pi} \times \pi A_s \left[d - \frac{d_g}{3} \right]$$

$$(MOR)_T = \frac{230}{\pi} \times 604.24 \times \left[650 - \frac{187.54}{3} \right]$$

$$(MOR)_T = 108667380.7 \text{ N-mm}^2$$

$$10.86 \text{ kN-m}$$

ET-1

★ Difference between limit state method & working stress method

	Limit State	Working Stress
1	It requires more calculation so it makes some difficulty to design.	It is easy for calculation.
2	Material strength are fully utilise in designing the member of structure.	Material strength are not fully utilise in design the member of structure.
3	It gives idea about the excess load which a structure can carry beyond the working load without collapse.	It does not gives idea about the excess load which a structure can carry beyond the working load without collapse.

4. This method is based on the actual stress strain curves for steel and concrete. For concrete the stress-strain curve is non-linear.

In this method concrete & steel are considered elastic and the strain curves are linear for both, and their moduli of elasticity are constant.

5. Design loads are obtained by multiplying partial safety factor of loads to the working loads.

No factor of safety is used for loads divided or multiplied.

6. This method gives economical design of structure.

This method gives uneconomical design of structure.

7. In this method actual load, permissible stress are according to probabilistic approach.

In this method actual load, permissible stress are according to serviceability approach.

Type of section:

1) Balance section:

If the area of steel reinforcement A_{st} is such that the magnitude of the permissible stress in concrete and steel are respectively are

developed simultaneously then the section is known as balanced section.

critical section or

economical section. For such a balanced section

the depth of actual neutral axis is equal to

the critical depth of neutral axis. For such a balanced section the moment of resistance obtained from the compressive force will be equal to the moment of resistance obtained from the tensile force.

ii) Under reinforced Section

An under reinforced section is one in which the percentage of steel provided is less than the required. In such a section the full strength of concrete in compression is not developed. The actual neutral axis of such a section will fall above the critical neutral axis of a balanced section.

iii) Over reinforced Section

In an over reinforced section the reinforcement provided is more than critical and therefore the actual neutral axis of such a section falls below the critical neutral axis of a balanced section.

Development Length

It is the length of reinforcement required to be either imbedded or projected in to the column to achieve the desired bond strength between the concrete and steel. The establishment of an adequate development length is critical for ensuring effective

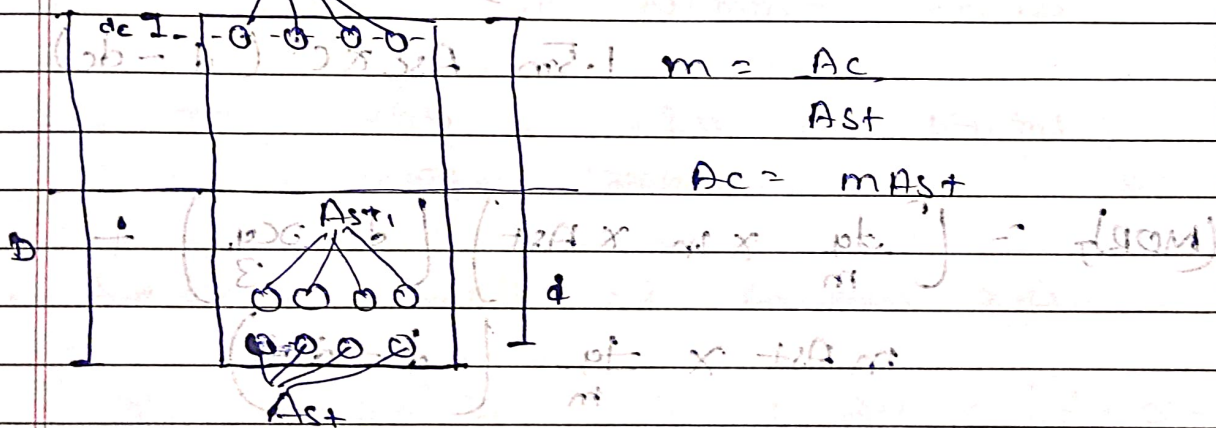
load transfer and structural integrity, preventing any potential failure.

Cur-tail bar:-

Cur-tail bar in a beam is a way of reducing the area of tensile reinforcement at points or areas where bending moment is minimum or zero for the purpose of achieving an economical design. Cur-tailment of tension reinforcement is flexural member

★ Analysis of Doubly Reinforced Section:-

$$f_c (b \cdot d) \times A_{sc} = m A_{st} \quad \left(\text{from } \sum F_x = 0 \right)$$



$$m = \frac{A_c}{A_{st}}$$

$$A_c = m A_{st}$$

i) Calculate critical neutral axis depth

$$x_c = \frac{m \sigma_{cbc}}{m \sigma_{cbc} + \sigma_{st}} \times d$$

ii) Actual depth of Neutral Axis

$$(b \times x_u) \times \frac{x_u}{2} = m A_s \times (d - x_u)$$

$$(b \times x_u \times \frac{x_u}{2}) = A_{sc} (x_u - d_c) + 1.5 m A_{sc} (x_u - d_c)$$

$$= m A_s (d - x_u)$$

iii) Comparison between x_u and $x_{u,lim}$

iv) Moment of Resistance

$(MOR)_{con}$

$$(b \times x_u \times \frac{x_u}{2}) \times (d - \frac{x_u}{3}) - A_{sc} C' (d - d_c) +$$

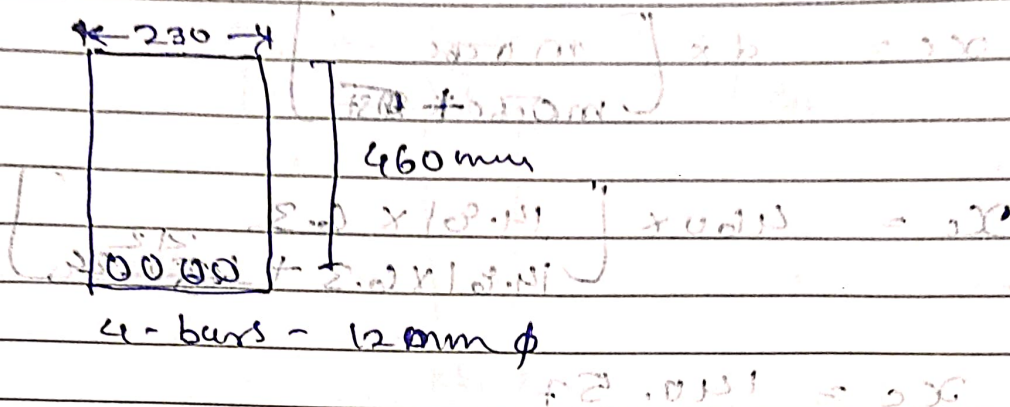
$$1.5 m A_{sc} C' (d - d_c)$$

$$(MOR)_s = \left(\frac{f_y}{m} \times m \times A_{st} \right) \left(d - \frac{x_u}{3} \right) + m A_{st} \times \frac{f_y}{m} \left(d - d_c \right)$$

Q:- Determine the position of neutral axis, which type of section it is and moment of resistance for a reinforced concrete beam 230 mm wide and 460 mm effective depth if the stress developed in concrete and steel are 6.3 N/mm^2 and 212 N/mm^2

respectively. 4 bars in 12mm ϕ (ii)

Ans: A



given data

$$b = 230 \text{ mm}$$

$$d = 460 \text{ mm}$$

$$A_{st} = 4 \times \frac{\pi}{4} \times 12^2 = 425.136 \text{ mm}^2$$

$$\sigma_{cbc} = 6.3 \text{ N/mm}^2$$

$$\sigma_{st} = 240 \text{ N/mm}^2$$

$$m = \frac{280}{6.3} = 44.44$$

$$\left[\frac{100 A_{st} \sigma_{st}}{b d \sigma_{cbc}} + 12 A_{st} \sigma_{st} \right] = \frac{100 \times 425.136 \times 240}{230 \times 460 \times 6.3} + 12 \times 425.136 \times 240 = 14.81$$

1) Actual depth of neutral axis

$$(b \times x_u) \times \frac{x_u}{2} = m A_{st} \times (d - x_u)$$

$$(230 \times x_u) \times \frac{x_u}{2} = 14.81 \times 425.136 \times (460 - x_u)$$

$$x_u = 137.814 \text{ mm}$$

ii) Critical depth of neutral axis

$$x_c = d \times \left[\frac{m \sigma_{cbc}}{m \sigma_{cbc} + \sigma_{st}} \right]$$

$$x_c = 460 \times \left[\frac{14.81 \times 6.3}{14.81 \times 6.3 + \frac{212}{452.36}} \right]$$

$$x_c = 140.57$$

iii) Compare

$$x_{ca} = 137.14 \text{ m} < x_c$$

$$x_c = 140.57 \text{ m}$$

under reinforced section

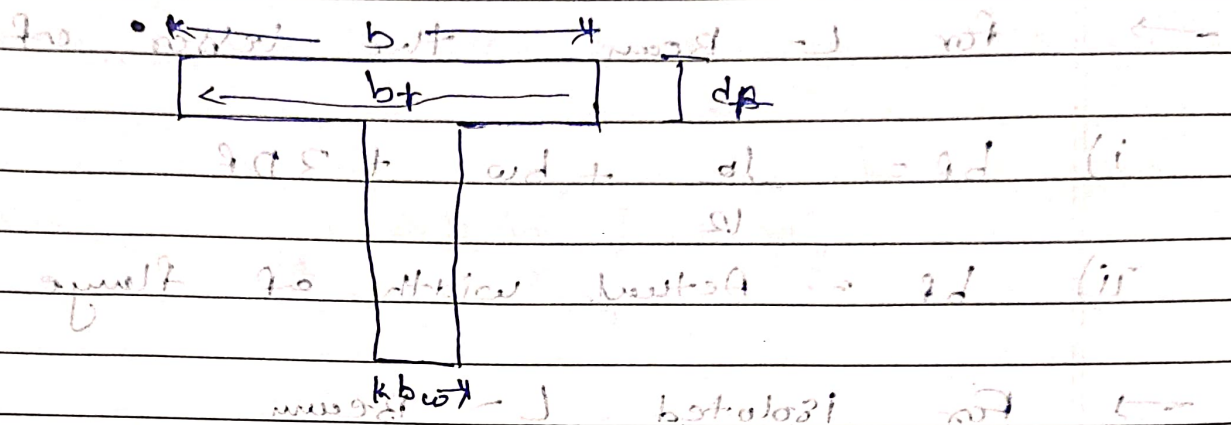
$$iv) (m_{or})_T = \sqrt{\sigma_{st} \times A_{st} \times \left(\frac{d - x_{ca}}{3} \right)}$$

$$= 212 \times 452.36 \times \left[\frac{460 - 137.14}{3} \right]$$

$$(m_{or})_T = 3.9731960 (4.8 \text{ mm})$$

$$3.9.73 < 4.8 \text{ mm}$$

* Analysis of T-beam



where b_f = effective width of the flange
 is equal to distance between point of zero moment in the beam which is the effective span for simply supported beams and $0.7l$ for continuous beams and frames.

b_w = width of web

d_f = Thickness of flange

b = Actual width of flange

* Effective width of flange

→ for T. Beam the lesser of

i) $b_f = \frac{l_0}{6}$

ii) $b_f = \text{Actual width of flange}$

→ For isolated T. Beam

$$b_f = \frac{l_0}{\left(\frac{l_0}{B}\right) + 4} + b_w$$

11) $b_f =$ Actual width of flange

→ for L-Beam the lesser of

i) $b_f = \frac{b_0}{12} + b_w + 3 D_f$

ii) $b_f =$ Actual width of flange

→ For isolated L-Beam

1) $b_f = 0.5 b_0 + b_w$

2) $b_f = \frac{(b_0)}{6} + 4 D_f$

3) $b_f =$ Actual width of flange

Step-01 critical depth x_d to neutral axis

$$x_d = \left(\frac{m \sigma_{sc}}{m \sigma_{sc} + \sigma_s} \right) \times d$$

Step-02 Actual depth x_d to neutral axis

Case-01 2N Axis line lying of flange

$$\left(\frac{x_d \times b_f}{2} \right) \times \sigma_{sc} + b_w \times \sigma_s (d - x_d)$$

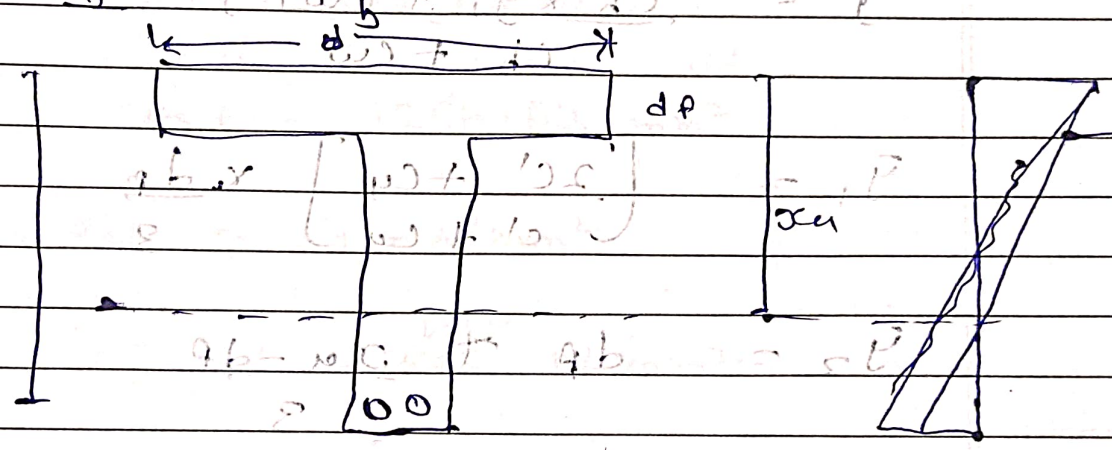
$\left[\frac{b \times d}{2} \right]$ if ...
 $\left[\frac{b \times d}{2} \right]$ if ...
 $\left[\frac{b \times d}{2} \right]$ if ...

Step-0 MOR for case 1 of ...

$$(MOR)_{com} = \left(\frac{b \times d}{2} \right) \times \left(\frac{d - x_{eq}}{3} \right)$$

$$(MOR)_{ten} = \left(\frac{b \times d}{2} \right) \times \left(\frac{d - x_{eq}}{3} \right)$$

Case - II



$$(b \times d) \times \left(\frac{d - x_{eq}}{2} \right) \times \left(\frac{d - x_{eq}}{3} \right)$$

$$(MOR)_e = (MOR)_{bri} + (MOR)_{flage} + (MOR)_{ar} + (MOR)_{uor}$$

MOR of flage

$$(b \times d) \times \left(\frac{c_1 + c_2}{2} \right) \times \left(1 - \frac{d_f}{3} \times \left(\frac{c_1 + c_2}{c_1 + c_2} \right) \right)$$

center of top flange = $\frac{b}{3} \left[\frac{b+2a}{b+a} \right]$

= $\frac{d_p}{3} \left[\frac{ca+2c}{ca+c} \right]$

MOR for web = $A_{st} \times L \times A$

$\left[\frac{b_w}{c} \right] \left[(x_u - d_p) \left(\frac{c+a}{2} \right) \right] \left[\frac{x - d_p}{3} \right]$

$(MOR)_c = \sum m A_{st} \times \frac{x}{m} (d - \bar{y})$

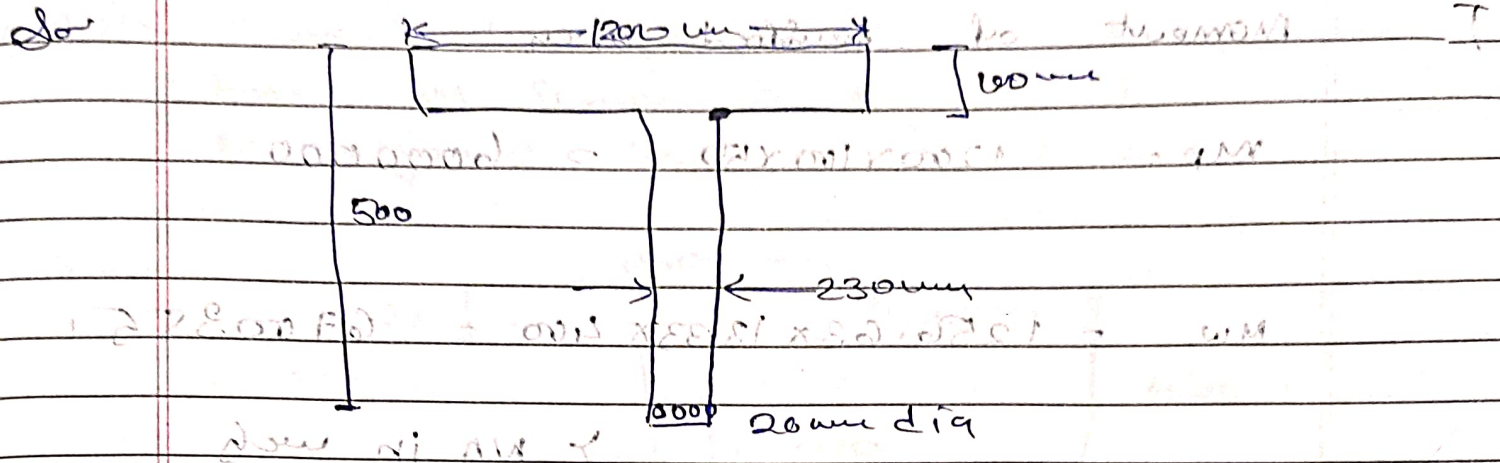
$\bar{y} = \frac{c_b \times \bar{y}_1 + c_w \times \bar{y}}{c_b + c_w}$

$\bar{y}_1 = \left[\frac{(2c' + c_u)}{c' + c_u} \right] \times \frac{d_p}{3}$

$\bar{y}_2 = d_p + \frac{x_u - d_p}{3}$

Ex 1. A beam with web width 230 mm, flange width 1200 mm, thickness of flange 100 mm and effective depth of 800 mm is reinforced with 4 number of 20 mm ϕ bars as tension reinforcement and cast concrete of critical depth & actual depth of neutral axis. The materials are M-20 grade concrete and Fe-260 steel.

$\left[\frac{b_w}{c} \right] \left[(x_u - d_p) \left(\frac{c+a}{2} \right) \right] \left[\frac{x - d_p}{3} \right]$



At the top -

$$A_{st} = 4 \times 25 = 250 \text{ mm}^2$$

downward moment. All

$$A_{st} = 1256.83 \text{ mm}^2$$

Concrete strength $f_{ck} = 25 \text{ N/mm}^2$ and

yielding strength $f_{yk} = 275 \text{ N/mm}^2$

$m = 18.33$ for B-33 steel

$$[A_b = \pi r^2 (0.01 + 0.005)]$$

i) Critical depth

$$\left(\frac{0.5 + \sqrt{0.25 + \frac{m \sigma_{cbc}}{\sigma_{st}}}}{m} \right) \times d$$

$$x_c = \left[\frac{18.33 \times 7}{18.33 \times 7 + 250} \right] \times 500$$

$$x_c = 193.96 \text{ mm}$$

Moment of transfer area

$$M_p = 1200 \times 100 \times 50 = 6000000$$

$$M_w = 1256.63 \times 13.33 \times 400 = 6700355$$

γ NA in web

$$M_w \gamma M_p = +20$$

NA lying in web

$$M_w \gamma M_p = +20$$

Taking moment of transfer area about neutral axis neglecting steel concrete in web portion.

Moment of transfer area

$$(1200 \times 100) \left[x_{ca} - \frac{d}{2} \right]$$

$$(1200 \times 100) \left[x_{ca} - \frac{100}{2} \right] = m A_s t \times (d - x_{ca})$$

$$1200 \times 100 \times \left[x_{ca} - \frac{100}{2} \right] = 13.33 \times 1256.63 \times (500 - x_{ca})$$

$$x_{ca} = 105.12 \text{ mm}$$

LIMIT STATE METHOD OF DESIGN and DESIGN OF RECTANGULAR BEAMS

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★ Limit State Method:-

- Limit states are the acceptable limits for the safety and serviceability requirements of the structure before failure occurs.
- The design of structure by this method will ensure that they will not reach limit state and will not become unfit for the use for which they are made.
- It is worth mentioning that structure will not just fail by exceeding the limit state. Failure therefore implies that the clearly defined limit state of structure use full as has been exceeded.

★ Limit State of Collapse:-

- Limit State of Collapse deals with the strength and stability of structure subjected to maximum design loads out of the possible combination of several type of loads.
- This limit state ensure that neither any part nor whole structure should collapse or become unstable under any combination of expected loads.
- Factors considered are Shear, flexure, torsion, Compression.

★ Limit State of Serviceability:-

- It deals with deflection and cracking

of structure under service loads. durability under working environment during adverse anticipated exposure condition during service, stability of structure as a whole; fire resistance, cracking deflection etc.

Partial Safety Factor γ = $\frac{\text{load } (X_k)}{\text{material } (X_m)}$

Structure should be designed with loads obtained by multiplying the characteristic loads with suitable factor of safety depending on the nature of loads or their combination and the limit state being considered.

These factor of safety for load are termed as partial safety factor for load and it is calculated by

Load Combination	Limit State of Collapse			Limit State of Serviceability		
	DL	LL	WL	DL	LL	WL
DL+LL	1.5		1.0	1.0	1.0	-
DL+WL	1.5		1.5	1.0		1.0
DL+WL+LL	1.2	1.2	1.2	1.0	0.8	0.8

Material strength

The characteristic strength of material as obtained from the statistical approach is the strength of that material below which not

more than 15% of the test result are expected to fail.

Concrete (f_{ck})

Steel (f_y)

The characteristics strength may differ from sample to sample also. Accordingly the design strength is calculated dividing the characteristics by a partial safety factor for the material.

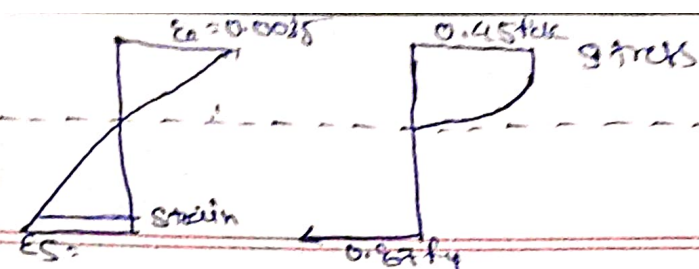
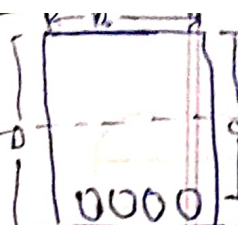
* Design strength is calculated as follows:

Design strength = $\frac{\text{characteristics strength}}{\text{partial safety factor}}$

	For Concrete			For Steel		
	f_{ck}			f_y		
	0.45 f_{ck}			0.87 f_y		
	1.5			1.15		
	0.1	0.9	0.9	2.1	1.15	
0.1	For Steel	2.1		f_y	0.87 f_y	
				1.15		
3.0	3.0	0.1	1.1	1.1	1.1	1.1

* Assumption of L.S.M.

- Plane section remains plane before and after bending.
- Strain diagram is linear and stress diagram is partially rectangular and



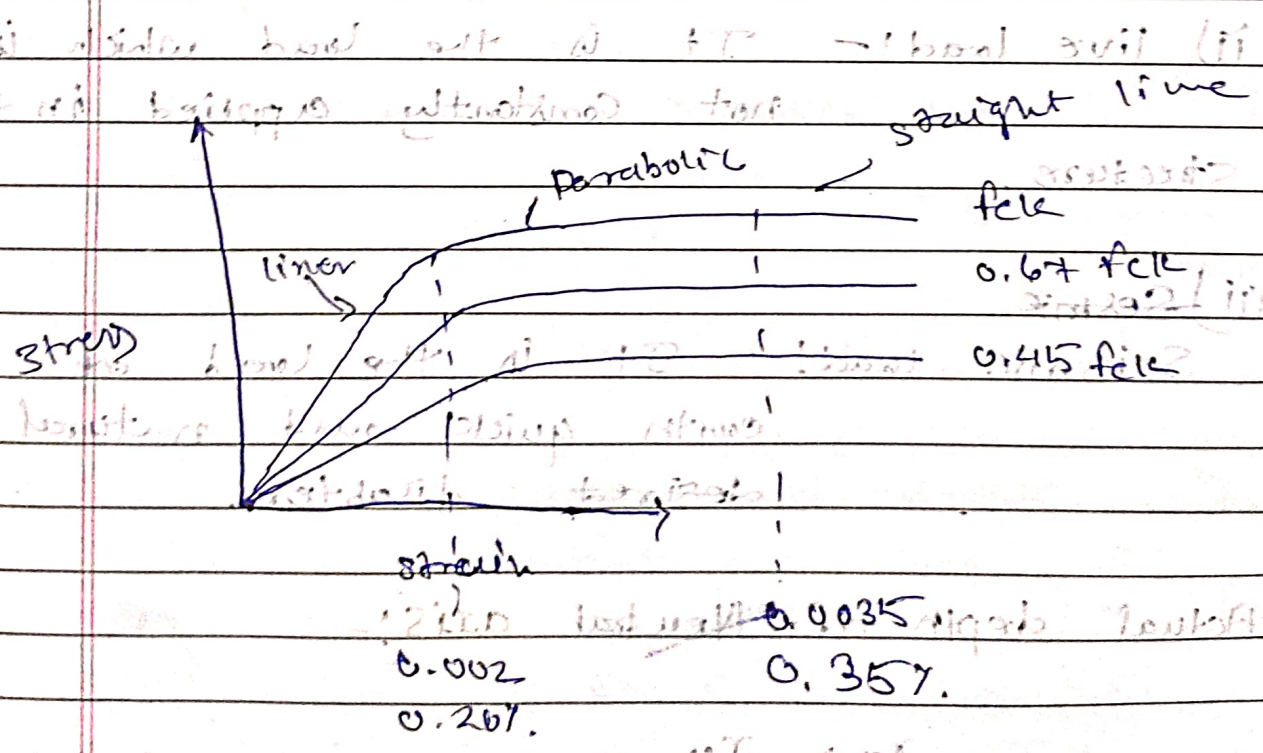
partially parabolic in shape.

→ The maximum strain in concrete in outer most compression fiber is taken as 0.35% in bending regardless of the strength of concrete.

→ The relationship between stress & strain distribution in concrete is assumed to be parabolic. The maximum compressive stress is equal to $0.67 f_{ck}$ or $0.445 f_{ck}$.

→ Tensile strength of concrete is neglected.
→ maximum strain in tension reinforcement in the section at failure should not be less than $\epsilon_s \geq 0.67 f_y + 0.002$ or $f_y + 0.002$.

Stress - Strain Relationship for Concrete



* Characteristics Strength of material:-

The strength of material which not more than 5% of test result are expected to fail is known as characteristic strength of material and denoted by (f)

Characteristic load:-

The value of load which has a 95% probability of not being exceeded during a life of structure is known as characteristic load.

i) dead load:- are due to the self weight of the structure.

ii) live load:- It is the load which is not constantly applied in the structure.

iii) Seismic

Seismic load:- It is the load of earth quake and natural disaster.

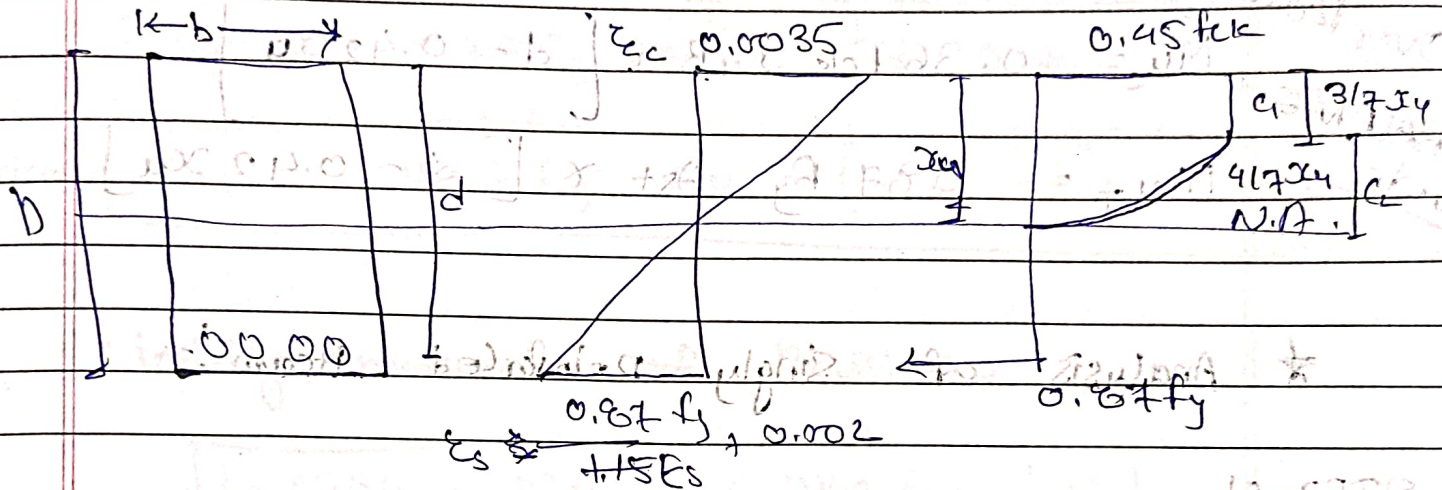
* Actual depth of Neutral axis:-

$$x_u = x_y$$

$$x_u = 0.4 \text{ lim.}$$

$$MOR = 1 - m_u \text{ (ultimate moment)}$$

$$f \text{ (characteristic strength)}$$



for lever arm

$$MOR = m_u = F \times \text{lever arm}$$

when we see compression side

$$M_u = C \times \text{lever arm} \quad (C \text{ Compression force})$$

$$C = C_1 + C_2 \quad \left(\text{Lever arm} = \frac{\text{stress} \times \text{area}}{\text{stress}} \right)$$

$$C_1 = 0.45 f_{ck} \times \left[\frac{3}{7} x_u \times B \right]$$

$$C_1 = \frac{0.45 f_{ck} \times \frac{3}{7} x_u \times B}{\text{stress} \times \text{area}} = 0.192 f_{ck} x_u B$$

Now

$$C_2 = \frac{0.45 f_{ck} \times \frac{2}{3} \times \frac{4}{7} x_u \times B}{\text{stress} \times \text{area}}$$

$$= 0.17 f_{ck} x_u B$$

$$C = 0.912 f_{ck} x_u B + 0.171 f_{ck} x_u B$$

$$C = 0.36 f_{ck} x_u B \quad [\text{compressive force}]$$

Over Reinforced

$$M_{uc} = 0.36 f_{ck} x_u B \times \left[d - 0.42 x_u \right]$$

BALANCE

Under

$$M_{ut} = 0.87 f_y A_{st} \times \left[d - 0.42 x_u \right]$$

* Analysis of Singly Reinforced Beam

STEP-01

Actual Depth of Neutral Axis

The actual depth of neutral axis is calculated by equating the compression force to tensile force.

$$0.36 f_{ck} x_u B = 0.87 f_y A_{st}$$

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

STEP 02

Limiting Depth of Neutral Axis

$$x_{u, \text{max lim}} = \left[\frac{700}{1100 + 0.87 f_y} \right] \times d$$

ULTIMATE

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Moment of Resistance

Over
Balanced

$$M_{uc} = 0.136 f_{ck} x_{u, \max} b \left[d - 0.42 x_{u, \max} \right]$$

$$M_{ut} = 0.87 f_y A_{st} \left[d - 0.42 x_{u, \max} \right]$$

Under

$$M_{u, r} = 0.87 f_y A_{st} \left[d - 0.42 x_{u, \max} \right]$$

Limiting moment of Resistance

$$R_e - 250 = M_{lim} = 0.149 f_{ck} b d^2$$

$$R_e - 415 = M_{lim} = 0.136 f_{ck} b d^2$$

$$R_e - 500 = M_{lim} = 0.133 f_{ck} b d^2$$

Limiting
Area of Steel

$$A_{st, lim} = \frac{0.36 f_{ck} x_{u, \max} b}{0.87 f_y}$$

$$A_{st, lim} = \frac{0.414 f_{ck} x_{u, \max} b}{f_y}$$

Percentage of Area of Steel

$$P_{st} = \frac{A_{st, lim}}{b \times d} \times 100 = \frac{0.414 f_{ck} x_{u, \max} b}{f_y b \times d} \times 100$$

A singly reinforced beam 200 mm wide & 400 mm deep to the center of tendon reinforcement. Determine limiting moment of resistance of the beam section and also the limiting area of reinforcement. Use M-20 concrete and Fe-250 steel.

Soln

given data:-

$$b = 200 \text{ mm}$$

$$d = 400 \text{ mm}$$

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

$$Fe-250 \quad f_y = 250 \text{ N/mm}^2$$

$$Mu_{lim} = 0.149 f_{ck} b d^2$$

$$Mu_{lim} = 0.149 f_{ck} b d^2$$

$$Mu_{lim} = 0.149 \times 20 \times 200 \times 400^2$$

$$Mu_{lim} = 95.36 \times 10^6 \text{ KN m}$$

Limiting area of Reinforcement

$$P_{st} = \frac{41.4 f_{ck}}{f_y} \times \frac{Mu_{max}}{d}$$

$$P_{st} = \frac{41.4 \times 20}{250} \times \frac{0.53}{400}$$

$$P_{st} = 1.76\%$$

limiting area of reinforcement

$$P_{st} = \frac{A_{st}}{b \times d} \times 100$$

$$1.76 = \frac{A_{st}}{200 \times 400} \times 100$$

$$A_{st} = 1408 \text{ mm}^2$$

A Simply Supported beam of 250 mm wide & 450 mm deep to the center of tensile reinforcement. Determine the limiting moment of resistance of the beam section and also the limiting area of reinforcement use M-20 & Fe-415 steel.

given data:-

$$M_{u \text{ lim}} = 0.138 f_{ek} b d^2$$

$$= 0.138 \times 20 \times 250 \times 450^2$$

$$= 139.72 \times 10^6 \text{ KN m}$$

$$P_{st} = \frac{41.4}{f_y} \times \frac{f_{ck}}{d} \times \text{Cuman}$$

$$P_{st} = \frac{41.4 \times 20}{415} \times 0.49$$

$$P_{st} = 0.96\%$$

$$P_{st} = \frac{A_{st}}{b \times d} \times 100$$

$$0.96 = \frac{A_{st}}{250 \times 450} \times 100$$

$$A_{st} = 1068 \text{ mm}^2$$

★ A Beam of rectangular section 250 mm wide 450 mm deep to the center of the tensile reinforcement is provided with 4 bars of 19 mm ϕ . Find the ultimate moment of resistance. Use M-20 concrete

given data:-

$$b = 250 \text{ mm}$$

$$d = 450 \text{ mm}$$

$$4 \text{ bars of } 19 \text{ mm}$$

$$A_{st} = 4 \times \frac{\pi}{4} \times 19^2 = 1017.87 \text{ mm}^2$$

0000 → 16mm φ

1-250 →

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

$$\text{or } f_{te} = 250 / 1.88$$

$$f_y = 250 \text{ N/mm}^2$$

i) Actual depth of neutral axis is

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

$$x_u = \frac{0.87 \times 250 \times 1017.87}{0.36 \times 20 \times 250}$$

$$x_u = 122.9 \text{ mm}$$

ii) x_{umax} is given by

$$x_{umax} = 0.53 \times d$$

$$= 0.53 \times 450$$

$$= 238.5 \text{ mm}$$

iii) Compare between x_{umax} & x_u

$$122.9 < 238.5$$

$$x_u = 122.9 \text{ mm}$$

$$x_{umax} = 238.5$$

Section under reinforced section

$$M_u = 0.87 f_y A_{st} x [d - 0.42 x_u]$$

$$M_u = \frac{88.19 \times 10^6}{1000} \text{ Nmm}$$

A singly reinforced beam 300 mm x 600 mm is reinforced with 2 bars of 25 mm dia. The effective cover is at 37.5 mm. Find the ultimate moment resistance of the beam section use M-20 concrete and Fe 415.

Soln

$$b = 300 \text{ mm}$$

$$d = 562.5 \text{ mm}$$

$$A_{st} = 2 \times \frac{\pi}{4} \times 25^2 = 981.74 \text{ mm}^2$$

$$Fe - 415$$

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

$$M - 20$$

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

① effective depth

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

$$x_u = \frac{0.87 \times 415 \times 981.74}{0.36 \times 20 \times 300}$$

$$x_u = 164.100 \text{ mm}$$

(11)

max. x_u may

$$0.48 \times d$$

$$= 0.48 \times 562.5 \text{ mm}$$

$$= 270 \text{ mm}$$

(11)

Compare

$$x_u = 164.100 \text{ mm}$$

$$x_{u, \text{lim}} = 270 \text{ mm}$$

under reinforced section

(iv)

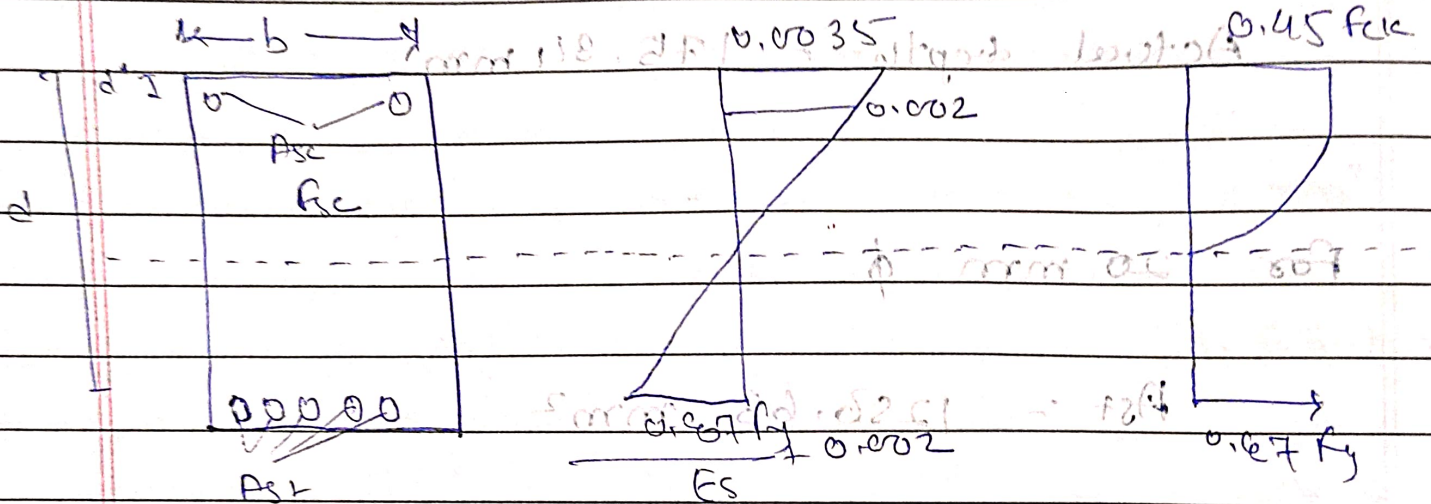
MOR

$$M_{uT} = 0.87 f_y A_{st} \times (d - 0.48 x_u)$$

$$M_{uT} = 0.87 \times 415 \times 981.74 \times [562.5 - 0.48 \times 164.100]$$

$$M_{uT} = 174.95 \times 10^6 \text{ KN mm}$$

* Doubly Reinforced Section



Step-1 Actual depth of NA

$$0.36 f_{ck} x_u b + A_{sc} f_{ck} = 0.87 f_y A_{st}$$

Step-2 Limiting depth of NA

Sum →

(3) Compare

(4) MOR

Over Reinforcement

$$M_u = 0.36 f_{ck} b x_u (d - 0.42 x_u) + A_{sc} f_{sc} (d - d')$$

Under Reinforcement

$$M_u = 0.87 f_y A_{st} (d - x_{umax})$$

★ Find the MOR of a beam section 230 mm wide & 460 mm effective depth reinforced with 2 bars of 16 mm dia as compression reinforc at an effective cover of 40 mm and 4 bars of 20 mm dia as tension reinforcement. The materials are M-20 grade concrete and mild steel reinforced - 250 250.

Sol

Given data:-

$$b = 230 \text{ mm}$$

$$d = 460 \text{ mm}$$

$$d' = 40 \text{ mm}$$

$$A_{sc} = 2 \times \frac{\pi}{4} \times 16^2 = 402.12 \text{ mm}^2$$

$$A_{st} = 4 \times \frac{\pi}{4} \times 20^2 = 1256.63 \text{ mm}^2$$

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

$$f_y = 250 \text{ N/mm}^2$$

① limiting depth of NA

$$\textcircled{1} f_y A_{st} = \sum m_{nom} = 0.53 d$$

$$= 0.53 \times 460$$

$$= 243.8 \text{ mm}$$

② ~~Actual~~ $f_{sc} = 0.0035 (\sum m_{nom} - d')$

$$= 0.0035 (243.8 - 40)$$

$$= 0.00217 \text{ } \Delta / \text{mm}^2$$

③ ~~$f_{sc} = 0.36 f_{ek} + A_{sc} f_{sc}$~~

$$x_u = \frac{0.87 \times 250 \times 1286.63}{0.36 \times 20 \times 230 + 402.12 \times 217}$$

$$x_u =$$

$$0.36 f_{ek} x_u b + A_{sc} f_{sc} = 0.87 f_y A_{st}$$

$$0.36 \times 20 \times x_u \times 230 + 402.12 \times 217 = 0.87 \times 250 \times 1286.63$$

$$x_u = 112.35 \text{ mm}$$

$$\sum m_{nom} = 243.8 \text{ mm}$$

③ Compare

$$x_u = 112.35 \text{ mm}$$

$$x_{u, \text{limit}} = 243.6 \text{ mm}$$

Hence the section is under reinforced section

④ MOP

$$M_u = 0.36 \times f_{ck} \times b \times x_u (d - 0.42 x_u) + A_{sc} f_{sc} (d - d')$$

$$M_u = 0.36 \times 20 \times 230 \times 112.35 (460 - 0.42 \times 112.35) + 402.12 \times 217 \times (460 - 40)$$

$$M_u = 113.45 \times 10^6 \text{ N mm}$$

★ Find the MOP of a beam section 300 mm wide $\times$ 450 mm effective depth reinforced with 2 bar of 20 mm dia as compression reinforcement at an effective cover of 50 mm and 4 bars of 25 mm ϕ as tension reinforcement. The material used are M-20 grade concrete and Fe 415

Sol given data:-

$$b = 300 \text{ mm}$$

$$f_{ck} = 20$$

$$d = 450 \text{ mm}$$

$$f_y = 415$$

$$d' = 50$$

$$A_{st} = 1963.49 \text{ mm}^2$$

$$f_c = 24.2 \text{ N/mm}^2$$

$$A_{sc} = 628.31 \text{ mm}^2$$

$\frac{d'}{d} \approx 0.11$ Taking next value of $f_{sc} = 342$

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① limiting depth of NA.

$$x_{umax} = 0.46 \times d$$

$$= 0.46 \times 450$$

$$x_{umax} = 208.7 \text{ mm}$$

② Actual depth of NA

$$0.36 f_{ck} x_u b + A_{sc} f_{sc} = 0.87 f_y A_{st}$$

$$0.36 \times 20 \times x_u \times 300 + 628.31 \times 342 = 0.87 \times 415 \times 1963.4$$

$$x_u = 228.72 \text{ mm}$$

③

Comparison

$$x_u = 228.72 \text{ mm}$$

$$x_{umax} = 208.7 \text{ mm}$$

At

This is less than x_{umax}

④

Mop

$$M_u = 0.36 f_{ck} b x_u (d - 0.42 x_u) + A_{sc} f_{sc} (d - d')$$

$$M_u = 0.36 \times 20 \times 300 \times 228.72 (450 - 0.42 \times 228.72) +$$

$$628.31 \times 342 \times (450 - 62.31) = 1963.4 \times 10^6$$

$$246.36 \times 10^6 = M_u = 162.40 \times 10^6 \text{ Nm}$$

$$M_u = 0.36 \times 20 \times 300 \times 228.72 \times (480 - 0.42 \times 228.72) + 628.31 \times 342 \times (480 - 80)$$

$$= 253.57 \times 10^6 \text{ N mm}$$

Q Find moment of resistance of a beam whose width is 200 mm and 400 mm effective depth the reinforcement on tension side is 4 bars of 20 mm ϕ and on compression side 2 bars of 20 mm ϕ the cover to compression reinforcement is 50 mm the material used are M-15 Concrete and Fe-250

$$b = 200 \text{ mm}$$

$$d = 400 \text{ mm}$$

$$A_{st} = 1256.63 \text{ mm}^2$$

$$A_{sc} = 628.31 \text{ mm}^2$$

$$d' = 50 \text{ mm}$$

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

$$f_y = 250$$

$$f_{sc} = 217 \text{ N/mm}^2$$

$$\frac{d'}{d} = 12 \text{ Taking next value of } f_{sc} = 217 \text{ N/mm}^2$$

Q Netural depth of NA

Q.

$$0.36 f_{ck} x_u b + A_{sc} f_{sc} = 0.87 f_y A_{st}$$

$$0.36 \times 15 \times 200 \times 126.82 + 628.31 \times 217 = 0.87 \times 250 \times 126.82$$

$$x_u = 95 \quad 126.82 \text{ mm}$$

②: x_{umax} is less than x_u so the section is over reinforced. $x_{umax} = 0.53 \times d = 0.53 \times 400 = 212 \text{ mm}$. Since $x_u > x_{umax}$, the section is over reinforced.

③ $x_{u,lim} = 126.82 \text{ mm}$
 $x_{u,lim} = 217 \text{ mm}$

Since the section is over reinforced section.

④

MOR

$$M_u = 0.36 f_{ck} b x_u (d - 0.42 x_u) + A_{sc} f_{sc} (d - d')$$

$$M_u = 0.36 \times 15 \times 200 \times 126.82 \times (400 - 0.42 \times 126.82) + 628.31 \times 217 \times (400 - 50)$$

$$M_u = 95.21 \times 10^6 \text{ N m}$$

T-BEAM

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T-Beam

CASE-I

When the depth of NA is in flange part

i) Actual depth of NA

$$x_u = 0.36 f_{ck} x_u \quad Bf = 0.67 f_y A_{st}$$

ii) Step -

Assume

iii) Compared -

iv) MOR

$$M_u = 0.67 f_y A_{st} (d - 0.42 x_u) \quad \text{Under}$$

reinforced

$$M_u = 0.36 f_{ck} b f \quad \text{Over}$$

reinforced

CASE-II

N.A. Portion is lies in web portion

i) When $317 x_u > Df$

ii)

iii)

i) Actual depth of N.A.

$$(0.36 f_{ck} b_w x_u) + 0.45 f_{ck} (b_f - b_w) D_f = 0.67 f_y A_{st}$$

ii) Limiting depth of N.A.

iii) Compure

iv) MOR

$$M_u = 0.36 f_{ck} x_u b_w (d - 0.42 x_u) + 0.45 f_{ck} (b_f - b_w) D_f \left[\frac{d - x_u}{2} \right]$$

$$D_f = 0.15 x_u + 0.65 D_f$$

2 ft) when $\frac{3}{7} x_u$ is Df

ii) Actual depth of N.A.

$$0.36 f_{ck} b_w x_u + 0.45 f_{ck} (b_f - b_w) y_f = 0.67 f_y A_{st}$$

i) Limiting depth of N.A.

ii) Compure

iv) MOR

$$M_u = 0.36 f_{ck} x_u b_w (d - 0.42 x_u) + 0.45 f_{ck} (b_f - b_w) y_f \left[\frac{d - y_f}{2} \right]$$

Question

A T-beam of effective flange with 1200 mm thickness of slab 100 mm width of rib 300 mm and effective depth of 560 mm is reinforced with 4 No. of 25 mm ϕ bar. Calculate MOP. The material used are M-20 grade concrete & Fe 415.

Solution

given data:-

$$b_f = 1200 \text{ mm}$$

$$d_f = 100 \text{ mm}$$

$$d = 560 \text{ mm}$$

$$b_w = 300 \text{ mm}$$

$$M = 20$$

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

$$f_y = 415$$

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

$$A_{st} = 4 \times \frac{\pi}{4} \times 25^2 = 1963.49 \text{ mm}^2$$

$$b_f = 0.36 f_{ck} b_f \times d_f$$

$$= 0.36 \times 20 \times 1200 \times 100 = 864000 \text{ N}$$

$$b_w = 0.87 f_y A_{st}$$

$$= 0.87 \times 415 \times 1963.49$$

$$= 708916.06 \text{ N}$$

N.N. will lie on flange

By

$$\textcircled{i} \quad 0.36 f_{ck} x_{ubf} = 0.87 f_y A_{st}$$

$$0.36 \times 20 \times x_{ubf} \times 1200 = 0.87 \times 415 \times 1963.49$$

$$x_{ubf} = 82.05 \text{ mm}$$

ii

Balance

$$= 0.48 d$$

$$= 0.48 \times 560$$

$$= 268.8 \text{ mm}$$

iii

Compare

$$x_{ub} = 82.05 \text{ mm}$$

$$x_{ubal} = 268.8 \text{ mm}$$

Under reinforced section is that

iv)

MOR

$$M_u = 0.87 \times f_y A_{st} (d - 0.42 x_{ub})$$

$$M_u = 0.87 \times 415 \times 1963.49 \times (560 - 0.42 \times 82.05)$$

$$M_u = 372.56 \times 10^6 \text{ N mm}$$

SLABDesign of 22.0 slab:-

Slabs are plate elements forming floors and roofs of the building and carry distribution loads. Inclined slabs are used as ramps for multistorey building and stairs.

IS code recommendations:-

→ minimum area of reinforcement
 $A_{st} \geq 0.12\% \text{ of total area} = 0.12\% \text{ of } 22.0 \times 22.0$
 $A_{st} \geq 0.15\% \text{ of total area} = 0.15\% \text{ of } 22.0 \times 22.0$

→ Maximum diameter of steel bar in slabs

$$\phi_{\text{min. max.}} = \text{Thickness of slab}$$

→ Maximum spacing of the reinforcement

$$i) \text{ main bar} = \text{less of } \begin{cases} 3d \\ 300\text{mm} \end{cases}$$

$$ii) \text{ Distribution bar} = \text{less of } \begin{cases} 5d \\ 300\text{mm} \end{cases}$$

$$(22.0 \times 22.0 - 6) \times 121 \times 22.0 = 9081$$

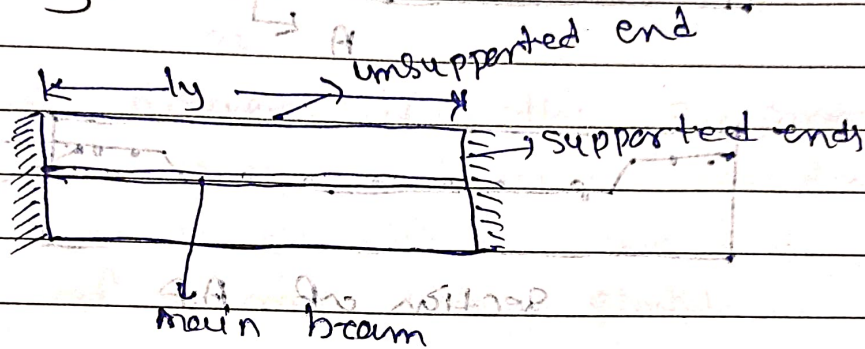
$$(22.0 \times 22.0 - 6) \times 121 \times 22.0 = 9081$$

$$(22.0 \times 22.0 - 6) \times 121 \times 22.0 = 9081$$

* Type of Slab:-

- i) one way Slab
- ii) Two way Slab

i) one way Slab:-



$$\frac{l_y}{l_x} \rightarrow 2 \quad [\text{greater than } 2]$$

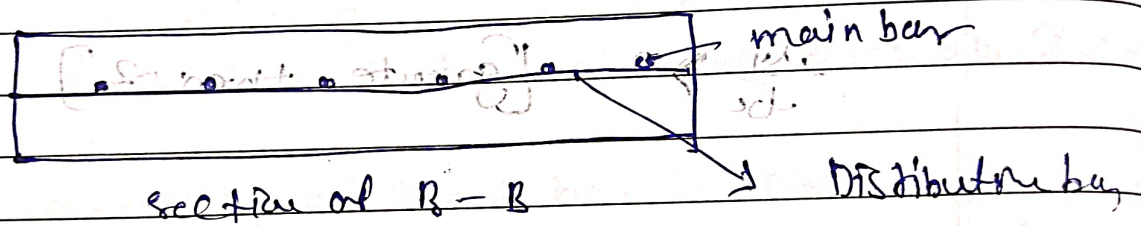
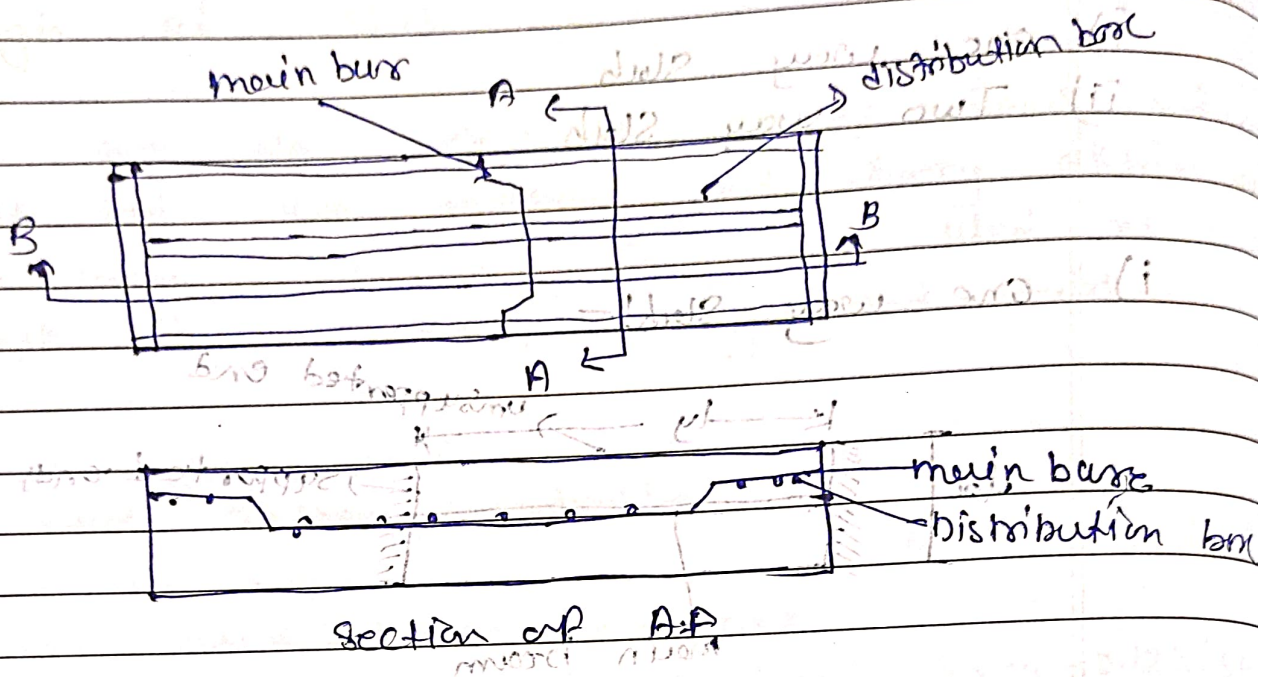
→ If Slab is supported on two opposite sides and l_y/l_x ratio is always one way slab.

→ If the slab is supported over two sides and l_y/l_x ratio is greater than 2 where $l_y \equiv$ longer dimension of slab and $l_x \equiv$ shorter dimension of slab.

NOTE one way slab is always design for shorter span.

→ If the slab is supported on all four edges and the ratio of longer span to shorter span is greater than 2 practically the slab across the shorter span such as slabs are also

designed as one way slab.



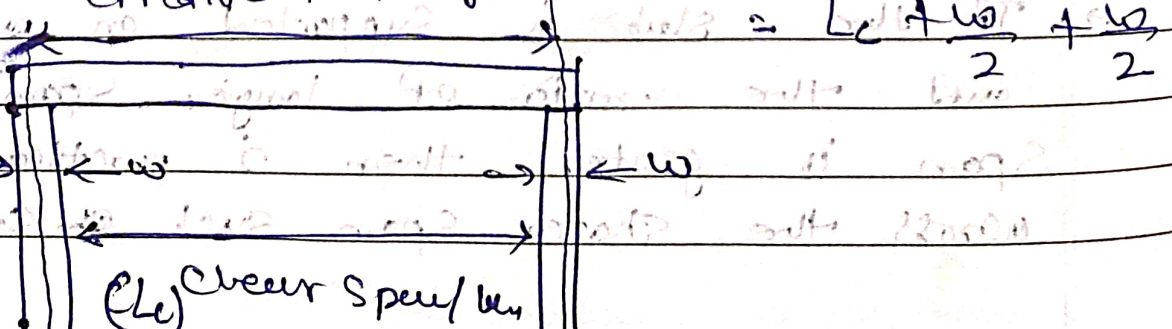
→ Distribution bars are always placed above the main bars.

Minimum dia of main bar is 10 mm for Fe-250 and 12 mm for HY SD. bar.

→ minimum dia of distribution bar is 6 mm in both the cases

★ Effective span of slab:-

Effective span / length



→ Simply supported beam or slab the effective span of the member is taken lesser of the following

- i) $l_c + d = l_c$
 - ii) $l_c + \frac{\text{width of the supported}}{2} + \frac{\text{width}}{2}$
- or

c/c distance of the support

Design of one way slabs

STEP (1) Find load over 1m. span

i) live load

ii) self weight - Thickness $\times 1 \times 25$

iii) floor finishing - Thickness of floor $\times 1 \times 25 \times 1$

STEP (2) Bending Moment

$$(BM)_{max} = \frac{w l^2}{8}$$

STEP (3) Area of steel

$$A_{st} = \frac{0.5 f_{ck}}{f_y} \left[1 - \sqrt{1 - \frac{4.6 BM}{f_{ck} B d^2}} \right] B \times D$$

EP (4)

check for shear $\tau_v = \frac{V}{Bd} \times \tau_{max}$ (not greater than)

W/Lt To allow 10% of

Determine the intermittent top of 150mm thick slab reinforced with 10 mm dia bar cut 200 mm center to center. The effective cover is 25 mm use m-20 concrete and Fe 415 steel.

34

given data:-

Thickness of slab = 150 mm

Reinforcement = 10 mm ϕ bars (200 mm)

effective cover = 25 mm

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

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

effective cover = $150 - 25 - 10/2$

Twice - eff cov. = half of dia

= 120 mm

Step (1) effective depth

= $150 - 25 - 10/2$

= 120 mm



Step-2 Area of reinforcement

(1 bar) Area of one bar $= \frac{\pi}{4} \times 10^2 = 78.53 \text{ mm}^2$

Number of bars in one meter = 5

$$1 \text{ m} = 1000 \text{ mm}$$

$$1 \text{ meter } \frac{1000}{200} = 5 \text{ bar}$$

$$A_{st} = 78.53 \times 5 = 392.65 \text{ mm}^2$$

Step-3 Moment of Resistance

$$M_u = 0.87 f_y A_{st} \left(d - \frac{\alpha_u}{2} \right)$$

$$\text{for } \alpha_u = 0.36 f_{ck} b x_{uL} = 0.87 f_y A_{st} \quad 392.65$$
$$0.36 \times 20 \times \frac{1000}{1000} x_{uL} = 0.87 \times 415 \times \frac{1000}{1000}$$

$$x_{uL} = 19.68 \text{ mm}$$

$$M_u = 0.87 f_y A_{st} \left[d - \frac{\alpha_u}{2} \right]$$

$$M_u = 0.87 \times 415 \times 392.65 \times \left[120 - \frac{19.68}{2} \right]$$

$$M_u = 15.61 \times 10^6 \text{ N mm}$$

Slab A simply supported one-way slab of
 clear span 3m and effective depth
 110 mm is subjected to total factor load
 of 9.375 kN/m. main steel of 9 mm ϕ
 @ of 150 mm center to center spacing is
 provided in which half bars are bending up.
 Distribution steel of 6 mm dia @ of 150
 mm c/c spacing is provided. The width
 of support is 350 mm. M-20 & Fe 415
 is used. calculate development
 length & dock width.

given data

Clear span = 3 m.

effective depth = 110 mm

Total load = 9.375 kN/m.

main steel = 9 mm ϕ bar @ 150 mm

distribution steel = 6 mm ϕ bar @ 150 mm

width of support = 350 mm

f_{ck} = 20 N/mm²

f_y = 415 N/mm²

Step-① Calculate effective span (Leff.)

$= L_c + \text{eff. depth}$

OR $= L_c + W_s$

$= 3000 + 110$

$= 3110$

$= 3000 + 350$

$= 3350$

we take $\therefore$

$\frac{3350}{2} = 1675$

1675

$$Left = 1675 \text{ mm}$$

Step ② Calculate effective depth $= 110 \text{ mm}$

Step ③ Calculate factored load $= 9.375 \text{ kN/m}$
(kN)

Step ④ Calculate bending moment $= \frac{wlL^2}{8}$ (Simply supported)

$$= \frac{9.375 \times 1675^2}{8}$$

$$= 3.28 \times 10^6 \text{ N mm}$$

Step 5 Calculate shear force

$$S.F. = \frac{wlL}{2} \quad (\text{Simple supported})$$

$$= 9.375 \times 1675$$

$$= 15695.625 \text{ kN m}$$

Step 6 Calculate Area of steel

for one bar

$$A_{st} = \frac{M}{f_y} \times \frac{1}{d} \times 10^6 = 50.26 \text{ mm}^2$$

Number of bar $= \frac{1000}{150} = 6.66 \approx 7$

Total $A_{st} = 50.26 \times 7 = 351.82 \text{ mm}^2$

Step-7 Calculate development length $l_d = \phi \frac{\sigma_s}{4\tau_{bd}}$

$\sigma_s = 415$ MPa
 $\tau_{bd} = 1.2$ MPa
 $\phi = 8$ mm

$$l_d = \frac{8 \times 415}{4 \times 1.2}$$

$$l_d = 601.75 \text{ mm}$$

Step-8 Calculate crack width

$$w = \frac{3 \sigma_{st} C_{dc}}{1 + 2 \left[\frac{b}{l_{eff}} \right]}$$

$\sigma_{st} = 15$ MPa, $l_c = 25$ mm, $d_c = 25$ mm
 $b = 1000$ mm, $l_{eff} = 1675$ mm

$$w = \frac{3 \times 15 \times 25 \times 25}{1 + 2 \left[\frac{1000}{1675} \right]}$$

$$w = 1281.86 \text{ mm}$$

★ Design For one way slab

Step-1 Given data

Step-2 Effective depth $\rightarrow$ [page No- 37 clause-23.2]
 $\frac{L}{d} \geq 20$

Step-3 Effective length

and or L_{eff} [net clear lth]

Step-4 load calculation

$\rightarrow$ i) Self weight (dead load)

$\left[b \times D \times \text{unit weight of R.C.C. (25)} \right]$

$\rightarrow$ ii) live load

$\rightarrow$ iii) floor finishing

$\rightarrow$ Total load = Sum of all loads

$\rightarrow$ (Wu) Factor load = Total load $\times 1.5$

$\rightarrow$ Factor Moment = $\frac{W_u l^2}{8}$

$\rightarrow$ Factor S.F. = $\frac{W_u l}{2}$

Step-5 check for Effective depth

d [Step-5] ϕ_{IST}

d [Step-1] $\phi_{IST} = 0.12$

Step-6

Calculate

A_{st}

[96
G.I.L.C.]

Main dia ϕ_{10} mm ϕ_{12} mm

Area of concrete bar $= \frac{\pi}{4} \times d^2 = A_{\phi}$

spacing $= \frac{b A_{\phi}}{A_{st}}$ (i.e. spacing)

A_{st}

question

Design a Slab over a room $3m \times 7m$
As per IS Code the edge of the
slabs are simply supported on a
bearing of 300 mm thick wall. Use
M-20 & Fe 415. Uniform distributed
load on slab is $2 kN/m^2$
Take unit weight of concrete 25
 kN/m^3

Ques

Given data

Step 1

$$\text{Size} = 13\text{m} \times 7\text{m}$$

$$\text{Support} = 300\text{ mm}$$

$$F_{ck} = 1.2 \times 20 \text{ N/mm}^2$$

$$F_y = 415 \text{ N/mm}^2$$

$$\text{live load} = 2 \text{ kN/m}^2$$

$$\text{unit weight} = 25 \text{ kN/m}^3$$

(W.L.D.)

Step 2 Effective depth

$$d = \frac{1}{20} \times 3000 = 150 \text{ mm}$$

$$d = 150 \text{ mm}$$

$$\text{effective depth} = 150 + 40 = 190 \text{ mm}$$

Step 3 Effective length

$$l_d \text{ or } l + w$$

$$3000 + 150 \text{ or } 3000 + 300$$

$$3150 \text{ mm or } 3300 \text{ mm}$$

$$l_e = 3150 \text{ mm}$$

Step 4 Load calculation

i) self load (dead load)

$$b \times D \times \text{unit weight}$$

$$1 \times 0.19 \times 28.5$$

$$= 4.75 \text{ kN/m}^2$$

$$\text{Live Load} = 2 \text{ kN/m}^2$$

$$\text{Total Load} = 6.75 \text{ kN/m}^2$$

$$\text{Factor Load (Wu)} = 6.75 \times 1.5$$

$$= 10.125 \text{ kN}$$

$$\text{Factor Moment} = \frac{W_u l^2}{8}$$

$$= \frac{10.125 \times 3.15^2}{8}$$

$$= 12.55 \text{ kNm}$$

$$\text{Factor S.B.} = \frac{W_u l^2}{2}$$

$$= \frac{10.125 \times 3.15^2}{2}$$

$$= 15.94 \text{ kNm}$$

Step 5 Check for Effective depth

$$M_u = 0.87 f_y \frac{x_{u, \max}}{d} \left[1 - 0.42 \frac{x_{u, \max}}{d} \right] b d^2 f_{ck}$$

$$12.55 \times 10^6 = 0.87 \times 415 \times 0.46 \times \left[1 - 0.42 \times 0.46 \right] 1000 \times d^2 \times 20$$

$$d = 67.44 \text{ mm}$$

Required depth $= 67.44 \text{ mm}$
 Provided depth $= 150 \text{ mm}$

0.67

Step 6

Calculate A_{st}

$$M_u = 0.87 f_y A_{st} d \left[1 - \frac{A_{st} f_y}{b d f_c} \right]$$

$$12.5 \times 10^6 = 0.87 \times 415 \times 150 \times \left[1 - \frac{A_{st} \times 415}{1000 \times 150 \times 20} \right]$$

$$A_{st} = 231.78 \text{ mm}^2$$

main dia. 10 mm

$$\text{Area of one bar} = \frac{\pi}{4} \times d^2$$

$$= \frac{\pi}{4} \times 10^2$$

$$A_{\phi} = 78.53 \text{ mm}^2$$

$$\text{Spacing} = \frac{b A_{\phi}}{A_{st}} = \frac{1000 \times 78.53}{231.78}$$

$$= 338 \text{ mm}$$

$$= 350 \text{ mm}$$

Step 7 check for shear

i) Nominal Shear Stress

$$\tau_v = \frac{V_y}{bd} = \frac{18.94 \times 10^3}{1000 \times 150} = 0.126 \text{ N/mm}^2$$

ii) Design Shear stress

$$\left[\frac{100 \times \frac{A_t}{b^2}}{b^2} \right] = 0.159$$

$$\tau_{cr} = 0.3 \text{ N/mm}^2$$

iii) Maximum shear stress

$$\tau_{cr} = 2.86 \text{ N/mm}^2$$

$$\tau_{cr} > \tau_v$$

$$\tau_{cr} > \tau_v$$

$$\tau_{cr} > \tau_v$$

$$0.159$$

COLUMNS

A Compression member whose effective length exceed three times its least lateral dimension is termed as column. The shape of the column may be square, rectangular, circular or any other shape depending on architectural requirement.

Columns are of two types short column & long column.

If Slenderness ratio is less than 12 then it is considered as short column according to IS 456-2000 and if the slenderness ratio is more than or equal to 12 then it is called as long column.

★ Design. (or) Short Column axially loaded
Square Column $500\text{ mm} \times 500\text{ mm}$ for a service load of 14000 kN Use $M-20$ & F_c-415

Given data

$$P = 14000\text{ kN}$$

$$\text{Dimension} = 500\text{ mm} \times 500\text{ mm}$$

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

$$F_y = 415\text{ N/mm}^2$$

Step-1 Ultimate Load $P_u = 1200 \text{ kN}$

$$P_u = 1200 \times 1.5$$

$$= 2100 \text{ kN}$$

$$2100 \times 10^3 \text{ N}$$

Step-2

Area of Steel (A_{sc})

From IS Code 456-2000 page No - 71
Clause 39.3

$$P_u \leq 0.4 f_{ck} A_c + 0.67 f_{yk} A_{sc}$$

$$A = A_c + A_{sc}$$

$$A = 800 \times 800$$

$$A_{sc} / A_c = A_{sc} / 640000 = 250000$$

From IS 456:2000 page No - 42 clause
25.4 minimum percentage of steel should be 20 min

$$SO \quad p = 0.05 \text{ (min)} \quad \text{provided} \quad \text{minimum}$$

$$= 0.05 \times 800$$

$$= 25$$

$$25 > 20$$

$$P_u = 2100 \times 10^3 \text{ N}$$

$$A_{sc} = 0.41 \times 2100 \times 10^3 / (34.15 \times 10^3) = 2576.80 \text{ mm}^2$$

$$A_{sc} = 2576.80 \text{ mm}^2$$

Assume 20mm ϕ bars used as main reinforcement

$$A_{\phi} = \frac{\pi}{4} \times 20^2 = 314.15 \text{ mm}^2$$

Minimum $A_{sc} = 0.8$ times of Cross Section Area
 Area of bars

Provide 8 bars of 20mm ϕ

Actual A_{sc}

$$314.15 \times 8 = 2513.28 \text{ mm}^2$$

Step - 3 Lateral ties

provide lateral ties of 6mm ϕ

$$\frac{1}{4} d < \phi$$

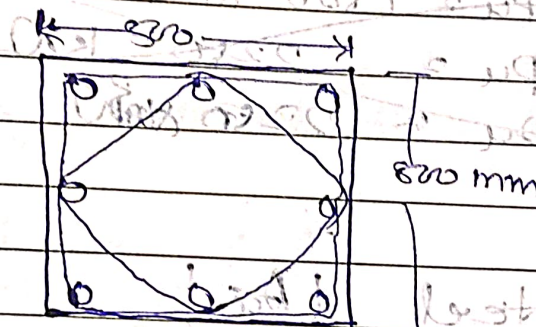
$$\frac{20}{4} < 6$$

$$5 < 6$$

Spacing should not exceed

- I) least lateral dimension ≤ 500 mm
- II) $16 \times$ dia of main bars
 $16 \times 20 = 320$ mm
- III) 300 mm

The main bar of 20 mm ϕ at 2 No. and $\frac{1}{4}$ ties bars at 6 mm ϕ at spacing of 300 mm should be provided



A Short Rec Column of size 450×450 mm has to carry an axial load of 1500 kN. Assume ρ minimum < 0.05 %. Design the Column using M20 grade concrete and $f_y = 415$ N/mm².

Sol

given

$$Size = 480 \times 480 \text{ mm}$$

$$P_u = 1800 \text{ kN}$$

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

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

1) Ultimate load

$$P_u = 1800 \text{ kN}$$

$$P_u = 1800 \times 1.5$$

$$P_u = 2700 \text{ kN}$$

$$P_u = 2700 \text{ kN}$$

2)

Area of Steel (A_{sc})

from IS Code 456:2000 page No. - 71

Clause 39.3

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

$$A = A_{sc} + A_c$$

$$A - A_{sc} = A_c$$

$$P_u = 0.4 f_{ck} (A_{sc} - A) + 0.67 f_y A_{sc}$$

$$1800 \times 10^3 = 0.4 \times 20 \times (480 \times 480 + A_{sc}) + 0.67 \times 415 \times A_{sc}$$

$$A_{sc} =$$

$$233290 \text{ mm}^2$$

$$= 444.36$$

Negative value indicates that there is no need for providing reinforcement. However minimum reinforcement should be provided.

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near it's
beled on
crete Area
required
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Assumed: 20mm ϕ bar used as main bar

$$A_{\phi} = \frac{\pi}{4} \times 20^2 = 314.15 \text{ mm}^2$$

provide 8 bar of 20mm ϕ

Actual $A_{sc} = 314.15 \times 8 = 2513.2 \text{ mm}^2$

Step-3

Lateral ties

providing lateral ties of 6mm ϕ

$$\frac{d}{4} < 6$$

$$\frac{25}{4} > 6$$

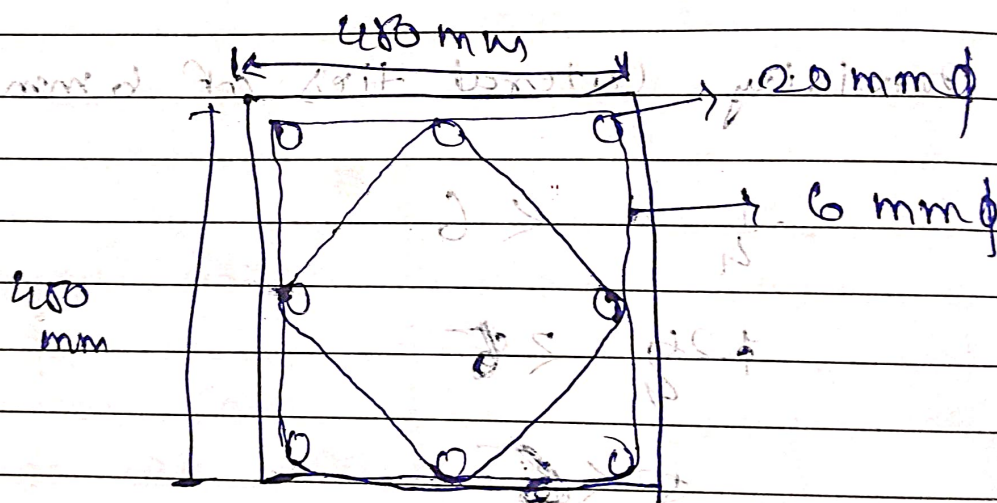
$$5 < 6$$

...

Spacing should be not exceed

- i) least central dimension = 450 mm
- ii) $16 \times \text{main dia} = 320 \text{ mm}$
- iii) 320 mm and 2ϕ spacing

The main bars $20 \text{ mm } \phi$ at 8 No.
ties bars $6 \text{ mm } \phi$ at spacing
 320 mm should be provided



* A Short Column $450 \text{ mm} \times 450 \text{ mm}$
reinforced with 4 No. 25 mm dia
Find the ultimate load bearing capacity of the column if the minimum
spacing is less than the minimum
dimension the code is used
 $f_c = 415$

given

$$\text{dimensur} = 400 \times 400$$

$$\text{No. of bar} = 4 \text{ in } 25 \phi$$

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

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

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

$$A = 400 \times 400$$

$$= 160000 \text{ mm}^2$$

$$A_{sc} = \frac{\pi}{4} \times 4 \times 25^2 = 1963.49$$

$$A_c = 160000 - 1963.49$$

$$= 158036.51 \text{ mm}^2$$

$$P_u = 0.4 \times 20 \times 158036.51 + 0.67 \times 415 \times 1963.49$$

$$P_u = 196102400.475 \text{ N}$$

* FOOTING *

Page

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Design of footing :-

Step 1 Size of foundation

- i) load on column - P
- ii) load on footing - P_f or weight of foundation 10% load on column
- iii) Total load - $P + P_f$
(P_t)

iv) Area of foundation

$$\sigma = \frac{P}{A} \Rightarrow A = \frac{P_t}{\sigma}$$

+ $\sigma = \text{Safe Bearing Capacity}$

$$A = \frac{P_t}{\sigma}$$

Now S.B.C

v) Decide dimensions of foundation

$$L \text{ or } B = \sqrt{A}$$

vi) Design Soil pressure (p) :- $\frac{P}{A}$

vii) Net Soil pressure

$$q_u = 1.5 \times p$$

Step-2 Check for bending moment or calculation of thickness of foundation

Critical section for bending moment will occur at a distance of a from the column.

$$(i) M_{max} = q_u B (L - a)^2 / 2$$

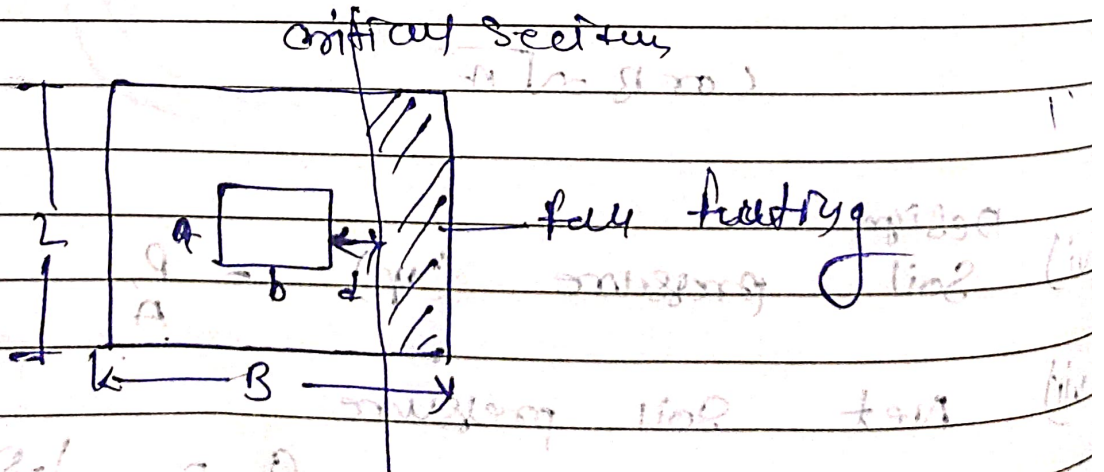
(ii) Thickness of foundation

depth (feet) $d = \sqrt{M_{max} / 0.136 f_k B}$

Assume $d = 400 / t$

Step-3 Check for one way shear

The critical section is considered at a distance of effective depth d from the face of the column.



Shear force in critical section equal =

$$V_u = q_u B \left[L - a - \frac{d}{2} \right]$$

Normal Shear Stress $\tau_v = \frac{V_u}{bd}$

Design Shear Stress $\tau_{cr} =$ IS 456:2000
Clause 40.2.1
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maximum $\tau_{cr \max}$

$$1 < \tau_{cr} < \tau_{cr \max}$$

O.K.

Step-4 Area of reinforcement $A_{st} = b \left[(b+d) + (b+d) \right] \phi$

$$A_{st \text{ req.}} = 0.5 \times \frac{f_{ck}}{f_y} \left[1 - \sqrt{1 - \frac{4.6 M_u}{f_{ck} b d^2}} \right] b d$$

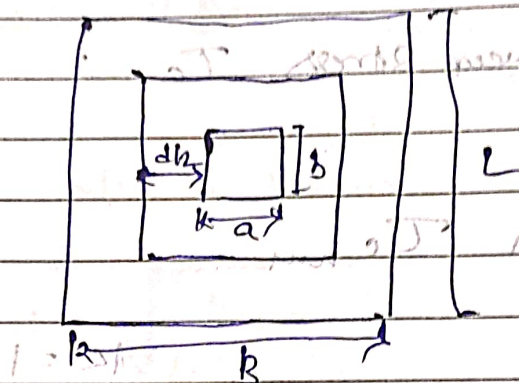
Assume 20 mm ϕ bar is used

Area of 1 bar = $\frac{\pi}{4} \times 20^2$

No. of bars = $\frac{A_{st}}{A_{\phi}}$

Step-5 Checks for Two-way shear

The critical section is considered at a distance of $\frac{d}{2}$ from the face of the column.



Resisting shear force $>$ Shear force of section

$$k_s 0.25 \sqrt{f_{ck}} > \frac{p_u - q_u (a+d)(b+d)}{2 [(a+d) + (b+d)] d}$$

For $k_s = 0.5$ and $\phi = 0.8$ we get

or $\phi \sqrt{f_{ck}}$

Value of ϕ is 0.8

Value of ϕ is 0.8

Value of ϕ is 0.8

Design a reinforced concrete footing to carry a
 axial load of 1200 kN through a
 column of size $450 \text{ mm} \times 450 \text{ mm}$ using
 4 bar of $25 \text{ mm } \phi$. Bearing capacity
 of soil is 105 kN/m^2 . Assuming footing
 to be 1.25 m below the ground level.

Use: M-25 & Fe-415

$P = 1200 \text{ kN}$ (iv)

dimens: $450 \text{ mm} \times 450 \text{ mm} = .45 \times .45 \text{ m}$

4 bar of $25 \text{ mm } \phi$

S.B.C. = 105 kN/m^2

$f_{ck} = 25 \text{ N/mm}^2$

$f_{yk} = 415 \text{ N/mm}^2$

depth of foundation = 1.25 m .

Step 1

size of foundation

(i) load on column = 1200 kN

(ii) weight of foundation = 10% of load of column

= 120 kN

(iii) Total load of foundation = $1200 + 120$
 = 1320 kN

(iv) Area of foundation

$$A = \frac{P}{S.B.C.} = \frac{1320}{105} = 12.57$$

≈ 11.42

S.B.C

105

m^2

① decide dimension of foundation

$$L = \sqrt{12.57}$$

$$L = 3.54 \text{ m}$$

$$L = 3.7 \text{ m}$$

Area of foundation = $3.7 \times 3.7 = 13.69 \text{ m}^2$
 $13.69 > 12.57$ O.K.

② design soil pressure

$$q = \frac{P_u}{A} = \frac{1320}{13.69} = 96.42$$

$$q = \frac{P_{sd}}{A} = \frac{1200}{13.69} = 87.65 \text{ kN/m}^2$$

③ Net Soil pressure

$$q_u = 87.65 \times 1.5$$

$$q_u = 131.47$$

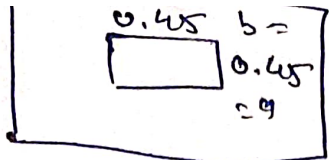
$$q_u = 131.47 \text{ kN/m}^2$$

Step ② $M_{max} = q_u B$

Check for bending moment & calculate thickness of foundation

$$M_{max} = \frac{q_u B (L-a)^2}{8}$$

$$M_{max} = \frac{131.47 \times 0.45 \times (3.7)^2}{8}$$



$$3.7 = L$$

$$3.7 = B$$

Page

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$$M_{max} = 131.47 \times 3.7 \times (3.7 - 0.45)^2$$

$$M_{max} = 166.56 \text{ kNm}$$

$$642.25 \text{ kNm}^2$$

$$642.25 \times 10^6 \text{ N-mm}$$

Thickness of reinforcement.

$$D \phi =$$

max

$$0.13\% \text{ for } \phi B$$

$$D \phi = 22 \text{ mm}$$

$$642.25 \times 10^6$$

$$0.13\% \times 25 \times 3700$$

$$D \phi = 22.430 \text{ mm}$$

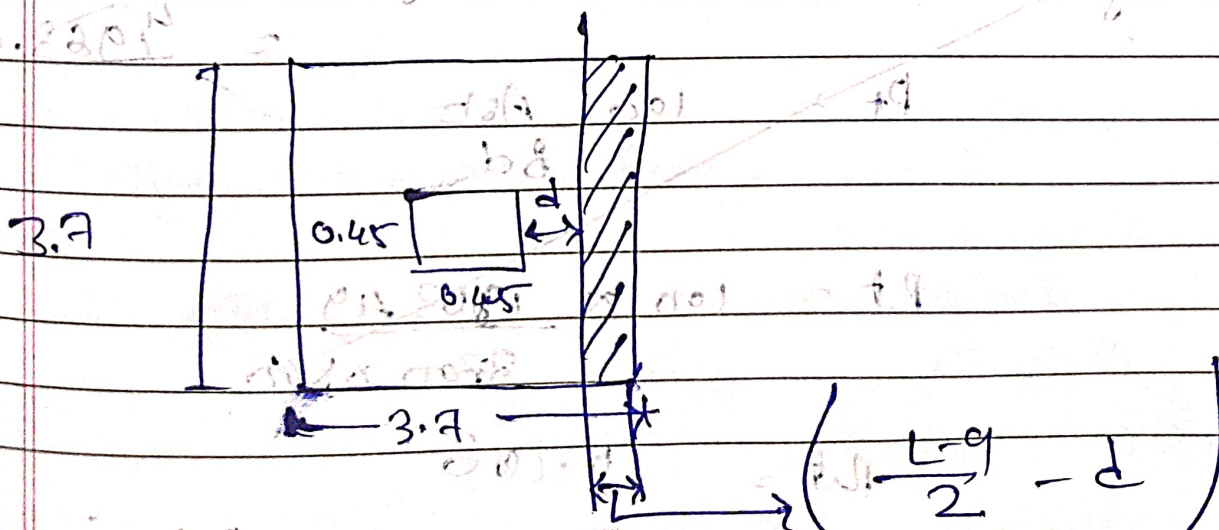
$$D \phi \approx 500 \text{ mm}$$

$$d = 500 - 75 - \phi = 500 - 75 - \frac{20}{2} = 415$$

Step-3 Check for one way shear

at B.C.C

The critical section is considered at a distance of effective depth d from the face of column.



Shear force in critical section

$$\text{Shear force} = q_u B \left[\frac{l - a}{2} - d \right]$$

$$= 131.47 \times 3.7 \left[\frac{3.7 - 0.45}{2} - 0.5 \right]$$

$$= 131.47 \times 3.7 \left[\frac{3.7 - 0.45}{2} - 0.5 \right]$$

$$= 547.28 \text{ kN/m}^2$$

$$\sigma_p = 0.547 \text{ N/mm}^2$$

Normal shear stress

$$\tau_v = \frac{V_u}{Bd} = \frac{0.47}{0.547} = 0.86$$

$$\tau_v = 547.28 \text{ N/mm}^2$$

$$= 295.82 \text{ N/mm}^2$$

$$\tau_v = 0.45 \times 0.5 = 0.225 \text{ N/mm}^2$$

Design shear stress

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

$$= 1963.49 \text{ mm}^2$$

$$P_t = 100 \times \frac{A_{st}}{Bd}$$

$$P_t = 100 \times \frac{1963.49}{3700 \times 800}$$

$$P_t = 0.106$$

required reinforcement

→ $A_{st} =$

$$A_{st} = 0.5 \frac{f_{ck}}{f_y} \left[1 - \sqrt{1 - \frac{4.6 M_u}{f_{ck} B d^2}} \right] B d$$

$$A_{st} = 0.5 \times \frac{25}{415} \left[1 - \sqrt{1 - \frac{4.6 \times 64225 \times 10^6}{25 \times 3700 \times (500)^2}} \right] \times 3700 \times 500$$

$$A_{st} = 3686.04 \text{ mm}^2$$

No. of reinforcement = $\frac{A_{st}}{\frac{\pi}{4} \times d^2}$ = $\frac{3686.04}{\frac{\pi}{4} \times 25^2}$

$$= 7.37 \approx 8$$

$A_{st} \text{ provided} = \frac{12 \times \pi \times 25^2}{4} = 23562.1$
 $= 3926.99 \text{ mm}^2$

→ Design Shear Stress

$$p = \frac{100 A_{st}}{B d} = \frac{100 \times 3926.99}{3700 \times 500}$$

$$= 0.21$$

$\tau_c = 0.32$ from IS Code 456:2000

$\tau_{cmax} = \frac{V}{b d} \cdot \frac{3}{2} \cdot \frac{1}{\tau_c}$

$\tau_{cmax} > \tau_c$
 $\tau_c > \tau_{cmax}$
 $\tau_{cmax} > \tau_c$

$\tau_c = 0.32$ from IS Code 456:2000

Maximum τ_{cmax}

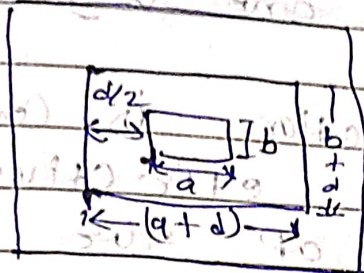
$\frac{V}{b d} \cdot \frac{3}{2} \cdot \frac{1}{\tau_c} > \tau_c$

$1 \times 0.32 > 0.29$

$0.32 > 0.29$

Next Step = Two way Shear Checking

The ~~critical~~ Critical Section is considered at distance $\frac{d}{2}$ from the face of the column.



Resisting Shear stress $\times$ Shear force at section

$$k_s 0.25 \sqrt{f_{ck}} \times P_u = q_u (a+d) (b+d) \\ 2 [(a+b) + (b+d)] H$$

$$k_s = 0.59 \text{ or } 1$$

$$0.5 \times 87.65$$

horizontal reinforcement

$$b d' \left[\frac{f_{yk}}{s} - \frac{1}{\gamma_s} \right] \leq \frac{A_{sh}}{s} \times 20 \times 7.0 = \frac{A_{sh}}{s}$$

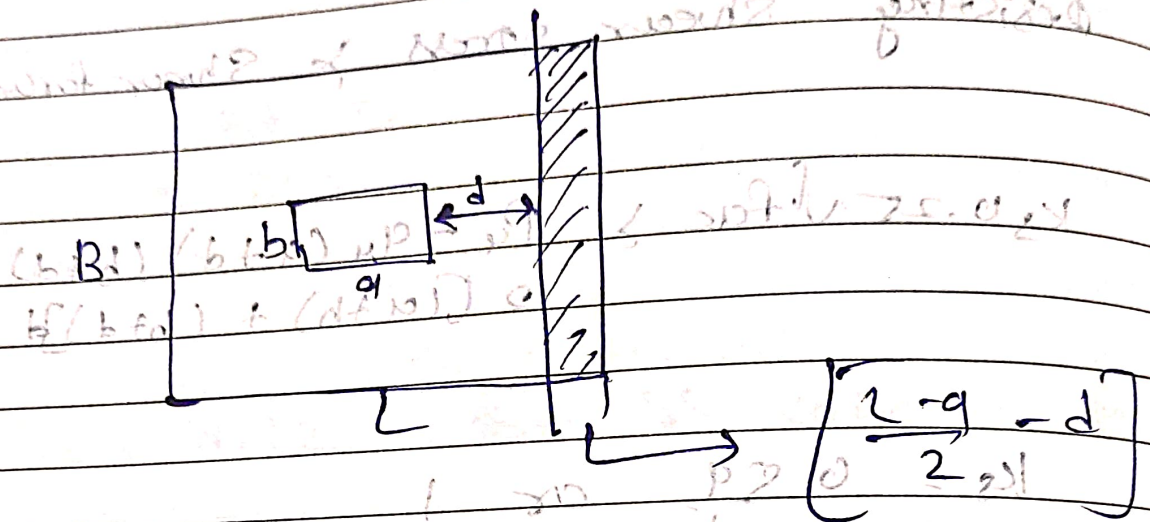
$$b d' \left[\frac{f_{yk}}{s} - \frac{1}{\gamma_s} \right] \leq \frac{A_{sh}}{s} \times 20 \times 7.0 = \frac{A_{sh}}{s}$$

vertical reinforcement

6/6

Step-3 @ check for one way shear

The critical section is considered at a distance of effective depth d from the face of the column.



→ Reinforcement Required

$$A_{st} = 0.5 \frac{f_{ck}}{f_y} \left[1 - \sqrt{1 - \frac{4.6 M_u}{f_{ck} b d^2}} \right] b d$$

$$A_{st} = 0.5 \frac{25}{415} \times \left[1 - \sqrt{1 - \frac{4.6 \times 642 \times 10^6}{25 \times 3700 \times 415^2}} \right] \frac{3700}{415}$$

$$A_{st} = 4508.22 \text{ mm}^2$$

We will provide reinforcement of 20 mm ϕ

No. of bars =

$$\frac{A_{st}}{\pi/4 \times d^2}$$

$$\frac{41586.22}{\frac{\pi}{4} \times 20^2} =$$

$$14.35$$

≈ 15 bars 20 mm ϕ

Area of Steel provided

$$15 \times \frac{\pi}{4} \times 20^2 = 5026.54 \text{ mm}^2$$

Step 4 Shear force for critical section

$$\text{Shear force} = q_u B \times \left[\frac{L - a}{2} - d \right]$$

$$\text{Shear force} = 131.47 \times 3.7 \times \left[\frac{3.7 - 0.45 - 0.45}{2} \right]$$

$$\text{Shear force} = 203.06 \text{ kN}$$

Nominal Shear stress = $\frac{V_u}{A_t}$

$$\tau_v = \frac{203.06}{3.7 \times 0.415}$$

$$= 119.32 \text{ kN/m}^2$$

$$= 0.36 \text{ kN/m}^2$$

$$= \frac{203.06}{3.7 \times 0.415}$$

$$= 119.32$$

$$= 0.36$$

$$\rightarrow p_t = \frac{100 \times A_{st}}{Bd} = \frac{100 \times 5026.84}{3700 \times 415}$$

$$= 0.32$$

$$\tau_{c, \text{act}} = 0.36 \text{ N/mm}^2$$

Condition for one way shear

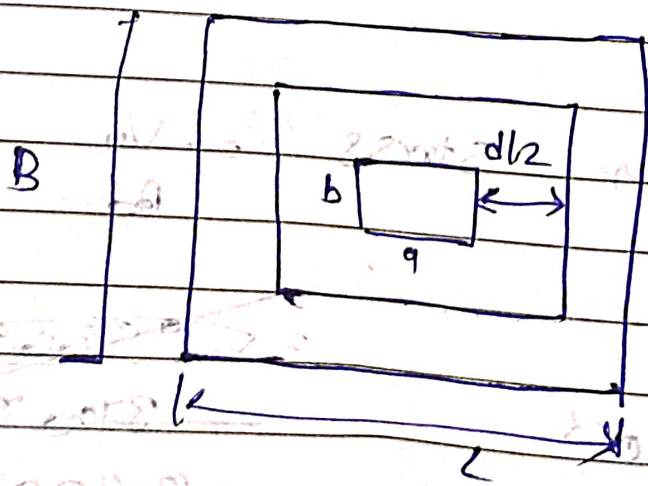
$$\tau_v \leq k \tau_c \quad k = 1$$

$$0.36 < 0.36$$

O.K.

Next Step: Check for Two-way Shear

The critical section will occur at a distance of $d/2$ from the face of the column.



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Resisting Shear force $\rightarrow$ Shear force at a section

$$1.5 \times 0.25 \sqrt{f_{ck}} \times P_u - q_u (a+b) (b+d) \\ 2 [(a+b) + (b+d)] d$$

$$k_s = \frac{0.5 + \frac{q}{b}}{1}$$

$$1 \times 0.25 \sqrt{25} \times 1200 \times 132.6 \times 10^3 \times (0.45 + 0.45) (0.45 + 0.45) \\ 2 [(0.45 + 0.45) + (0.45 + 0.45)] \times 0.45$$

1.25 $\times$

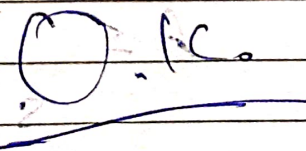
all dimensions

in mm

$$1.25 \times \frac{q_u (13.2 - (a+b)^2)}{2 [(a+b) + (b+d)] d} \\ = 1164939.67 \text{ N/mm}^2$$

$$1.25 \times 1.196 \text{ MN/m}^2 = 1.495 \text{ MN/m}^2$$

$$\frac{(l^2 - l(a+b))}{(a+b)d}$$



UNIT - 5

STAIR CASE

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Structural Components of Stair case:-

Tread:- 250 mm - 300 mm

Riser:- 150 mm - 180 mm

width of stair:- 1.5 m. or more
450 mm

landing:- 1.25 m x 1.5 m

width:- 2.0 m

Design Step for Staircase

Step-1 General arrangement

→ Rise & Tread

→ width of flight

→ Height of flight

→ Number of rise

→ Number of treads (Rise - 1)

→ Space occupied by treads (No. of treads x width of tread)

→ width of landing

Step-2 Loading on each flight

→ Effective span

→ weight of slab

→ Dead weight of slab

→ weight of finishing

→ live load

→ Total weight

Step-2 Design of waist slab:-

→ Bending moment $\left[\frac{w l^2}{8} \right]$

→ Factored moment

→ depth $d = \sqrt{\frac{M_u}{0.138 f_{ck} b}}$

→ Reinforcement

$$A_{st} = 0.5 \frac{f_{ck}}{f_y} \left[1 - \sqrt{1 - \frac{4.6 M_u}{f_{ck} b d^2}} \right] b d$$

→ Assuming main bar $\phi 12 \text{ mm}$

→ Assuming distribution bar

Design a stair for a building which the vertical distance between two floor is 3.6 m. The stair shall measure 2.5 x 5 m. the live load may be taken as 2500 N/m². Use M20 & Fe-415.

given =

height of floor = 3.6 m.

stair hall = 2.5 x 5 m.

live load = 2500 N/m²

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

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

Step-1 General Arrangement.

→ Tread - let rise be $\sim 150 \text{ mm}$

$$\text{tread } b_r = 250 \text{ mm}$$

width of each flight $\sim 1.0 \text{ m}$

$$\text{Height of each flight} = \frac{3.6}{2} = 1.8 \text{ m}$$

$$\text{No. of rise} = \frac{1.8}{0.15} = 12$$

$$\text{Tread} = (12 - 1) = 11$$

$$\text{Space occupied by tread} = 11 \times 250 = 2750 \text{ mm}$$

Assume width of landing $\sim 1.25 \text{ m}$

Step-2 Loading of each flight

→ let the bearing of the landing slab in the wall be 160 mm

$$L_e = 1.25 + \frac{2.750 + 0.160}{2}$$

$$L_e \approx 2.75 + 1.455 \text{ m}$$

$$\text{Effective } L_e \approx 4.205 \text{ m}$$

→ Thickness of least waist slab $= \frac{L_e}{20}$

$$= \frac{4.205}{20} = 0.21025 \text{ m}$$

$$\approx 210 \text{ mm}$$

→ weight of slab (W_1) = $0.205 \times 1 \times 25$
 $= 5.125 \text{ kN/m}^2$
 $= 5125 \text{ N/mm}^2$

→ Dead weight of Horizontal area

$= W_1 \sqrt{R^2 + T^2}$
 $T = \text{Total}$

$= 5125 \sqrt{180^2 + 250^2}$

$W_1 = 5830 \text{ N/mm}^2$

→ Dead weight of steps

$W_2 = \frac{R}{2} \times 1 \times 25$

$W_2 = 1.875 \text{ kN/m}^2$
 $= 1875 \text{ N/mm}^2$

Total dead + live

$W_1 + W_2$

$= 5830 + 1875$

$= 7705 \text{ N/mm}^2$

1.3 Finish load = 1 kN

(1000 N)

line load = 2800 N/mm^2

Total load = 10305 N/mm^2

$$D =$$

$$M_y$$

$$\sqrt{0.138 \times f_{ck} \times b \times d}$$

bd = width of slab = 1000 mm
factored moment

$$M_y = 2912.58 \times 10^3 = 108.77 \text{ mm}^2$$

$$A_{st} = 1000 \times D \times 112 \text{ mm}$$

③ Design waist of RCC slab

$$\text{Bending moment} = \frac{wL^2}{8}$$

$$M = \frac{10.365 \times 21.00^2}{8}$$

$$= 21.65 \times 10^6 \text{ Nmm}$$

$$\text{Factored moment} = 21.65 \times 10^6 \times 1.5$$

$$= 32.475 \times 10^6 \text{ Nmm}^2$$

$$\text{Clear width} = 1000 \text{ mm}$$

$$\text{effective depth} = 1120 - 10 - \frac{\phi}{2}$$

$$1120 - 10 - \frac{6}{2}$$

$$= 99 \text{ mm}$$

Reinforcement

$$\rightarrow A_{st} = 0.85 \frac{f_{ck}}{f_y} \left[1 - \sqrt{1 - \frac{4.6 m_y}{f_{ck} b d^2}} \right] b d$$

$$= 0.85 \times \frac{20}{415} \left[1 - \sqrt{1 - \frac{4.6 \times 32.475 \times 10^6}{20 \times 1000 \times 99^2}} \right] \times 1000 \times 99$$

$$= 1221.97 \text{ mm}^2$$

using 12 mm ϕ bar No. of bars provided

$$\frac{A_{st}}{A_{\phi}} = \frac{1221.97}{\frac{\pi}{4} \times 12^2} = 10.77$$

$$\text{Spacing} = \frac{12 \times 1000}{10.77} = \frac{A_{st} \times 1000}{A_{\phi}}$$

$$= \frac{1221.97 \times 1000}{12}$$

$$\text{Spacing} = \frac{113.09 \times 1000}{1221.97} = \frac{A_{\phi} \times 1000}{A_{st}}$$

$$\text{Spacing} = 92 \text{ mm}$$

Use 12 mm ϕ bars @ Spacing of 92

Distribution bars

Use 8mm ϕ bars at 200mm spacing at

200mm

