LECTURE NOTES

STRUCTURAL DESIGN -I

PREPARED BY MRS. ARPITA SAMAL

LECTURE IN CIVIL ENGINEERING

Working stress Method:
(INTRODUCTION)

Objectives of design and detailing :-

The objects of reinforced concrete design is to achieve a structure that will result in a safe and economical solⁿ.

PROPERTIES OF CONCRETE :-

(i) Though it consists of different materials like cement, sand and aggregate the intimate mixture is so good that for all practical purpose it may be assumed as homogeneous.

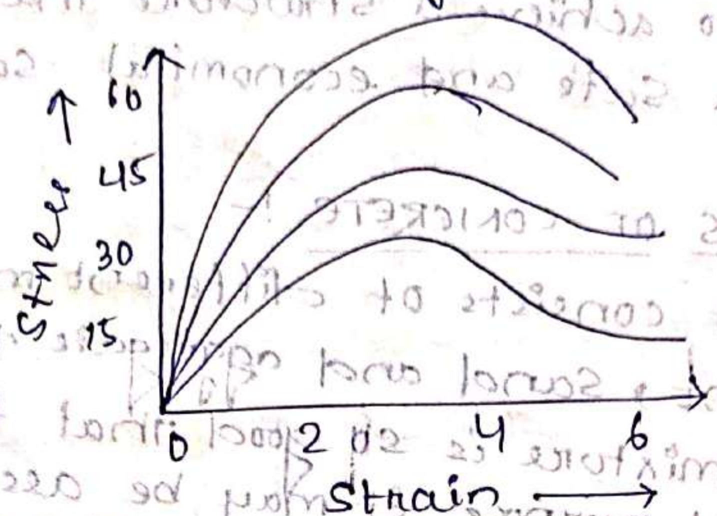
(ii) For concrete, characteristic strength (f_{ck}) is defined as compressive strength of 150mm cube at 28 days in N/mm^2, below which not more than 5 percent cubes give the result.

Grade of concrete

Group	Grade	Characteristic strength N/mm^2
Ordinary/lean concrete	M_{10}	10
	M_{15}	15
	M_{20}	20
Standard concrete	M_{25}	25
	|	|
	M_{55}	55
High strength concrete	M_{60}	60

(iii) Stress - Strain relationship :-

Stress-strain curve depend on strength of concrete as well as on the rate of loading



(iv) Tensile Strength :-

$$\boxed{f_{cr} = 0.7\sqrt{f_{ck}}}\ N/mm^2$$

where,
f_{cr} = flexural tensile strength
f_{ck} = characteristics compressive strength.

(v) MODULUS OF ELASTICITY :-

The modulus of elasticity is primarily influenced by the elastic properties of the aggregate and to a lesser extent by the conditions of curing and age of the concrete, the mix proportions and the type of cement.

The modulus of elasticity of concrete is normally related to the compressive strength of concrete.

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

(vi) Poisson's Ratio :-

* It is taken as 0.1 for high strength concrete and 0.2 for weak concrete.

* Usually it is taken as 0.15 for strength and 0.2 for Serviceability Calculation.

(vii) SHRINKAGE :-

Total amount of shrinkage in concrete depends on the various factors including the amount of water present at the time of casting. The total shrinkage value may be taken as 0.0003.

(viii) CREEP :-

It depends on various factors including the age of loading, duration of loading and stress level.

The creep co-effecient can be defined as the ratio of ultimate creep strain to elastic strain at the age of loading.

Age at loading	Creep co-effecient
7 days	2.2
28 days	1.6
1 year	1.1

PROPERTIES OF STEEL :-

(i) It is treated as homogeneous material.
~~and it is really~~

(ii) The characteristic strength of steel (fy) is its tensile strength determined on standard specimen below which not more than 5 percent specimen give the results.

Type	Grade of steel	fy
Mild steel	Fe 250	250 N/mm²
HYSD/ TMT	Fe 415 Fe 500	415 N/mm² 500 N/mm²

(iii) The Young's modulus (E) for all grades of steel is taken as 200 KN/mm² $= 2 \times 10^5$ N/mm²

LOADS:-

The various loads expected on a structure may be classified into the following groups:-

(i) Dead load
(ii) Imposed load (live load)
(iii) Wind load
(iv) Snow loads
(v) Earthquake forces
(vi) shrinkage, creep and temp. effects

(vii) Other forces

DEAD LOAD :-

(i) Dead loads in a building includes the weight of all permanent construction like roofs, floors, walls, partition walls, beams, columns, balcony's, footing.

(ii) These loads shall be assessed by estimating the quantity of each material and then multiplying it with the unit weight.

IMPOSED LOAD OR LIVE LOAD :-

The loads which keep on changing from time to time are called as imposed loads.

eg :- In a building are the weight of the person, weight of movable partitions, weight of furniture, dust load and

LOAD COMBINATION :-

1. DL
2. DL + IL
3. DL + WL
4. DL + EL
5. DL + TL
6. DL + IL + WL
7. DL + IL + EL
8. DL + IL + TL
9. DL + WL + TL
10. DL + EL + TL
11. DL + IL + WL + TL
12. DL + IL + EL + TL

WORKING STRESS METHOD

OBJECTIVES OF DESIGN AND DETAILING:

1) Structures and structural element should be designed ~~to have~~ for Stability, strength and serviceability.

(1) STABILITY:—

To prevent overturning, sliding or buckling of the structure or parts of it under the action of loads.

(2) STRENGTH:—

To resist safety the stresses induced by the loads in the various structural members.

(3) SERVICEABILITY:—

To ensure satisfactory performance under service load conditions. which implies providing adequate stiffness and reinforcements to contain deflections, crack widths and vibrations within acceptable limits and also providing impermeability and durability etc.

There are two other considerations that ~~that~~ are :- economy and aesthetics.

DIFFERENT METHOD OF DESIGN CONCRETE STRUCTURE :-

The design philosophies used in RCC are :- (i) Working stress method (WSM)
(ii) Ultimate load method (ULM) OR Load factor method (LFM)
(iii) Limit state method (LSM)

(i) WORKING STRESS METHOD :-

(i) This method is also known as "Modular Ratio method" or "Elastic stress method".

(ii) In this method, the moment and force acting on a structure are computed from the actual values of service load.

(iii) A factor of safety of 3 in concrete and 1.78 to 1.80 in steel generally adopted in this method.

ASSUMPTIONS :-

(i) At any cross-section, plane section before bending remains plane even after bending.

(ii) All tensile stresses are taken by reinforcement and none by concrete.

(iii) The stress-strain relation, under working loads is linear both for steel and concrete.

(iv) The modular ratio between steel and concrete remains constant.

$$\boxed{m = \frac{E_s}{E_m} = \frac{280}{3\sigma_{cbc}}}$$

Where, σ_{cbc} = permissible compressive stress in bending.

PERMISSIBLE STRESS :-

"It can be defined as ultimate stress divided by a factor of safety."

Incase of steel, the permissible stress is defined as yield stress or 0.2 percent proof stress divided by factor of safety.

ULTIMATE LOAD METHOD :-

~~This method is used as design load and~~ (i) In this method ultimate load is used as design load and the collapse criteria used for the design.

This method is also known as "Load factor method".

(ii) It involves the analysis of sections at failure, the actual strength of a section is related to the actual load causing failure, with latter being determined by "Factorising" the design load.

LIMIT STATE METHOD :-

(i) In this method of design based on limit state concept, the structure shall be designed to withstand safely all loads liable to act on it throughout its life, It ~~a~~ shall also satisfy the serviceability requirements such as prevention of excessive deflection, excessive cracking and excessive vibration.

(ii) The acceptable limit for the safety and serviceability requirements before failure occurs is called "limit state".

* Permissible stresses in concrete — code page no-81 table no-21

Page no 80 ASSUMPTIONS IN WSM :-

(i) Concrete is assumed to be homogeneous.

(ii) At any cross-section, plane sections before bending remain plane after bending.

(iii) The stress-strain relationship for concrete is a straight line, under working loads.

(iv) The stress-strain relationship for steel is a straight line, under working loads.

(v) Concrete area on tension side is assumed to be ineffective.

(vi) All tensile stresses are taken up by reinforcement and none by concrete.

(vii) The steel area is assumed to be concentrated at the centroid of the steel.

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

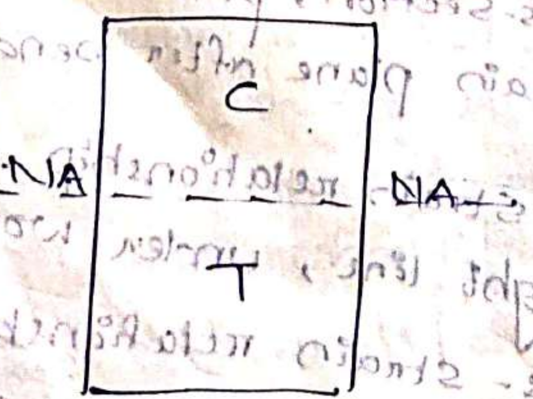
Where,

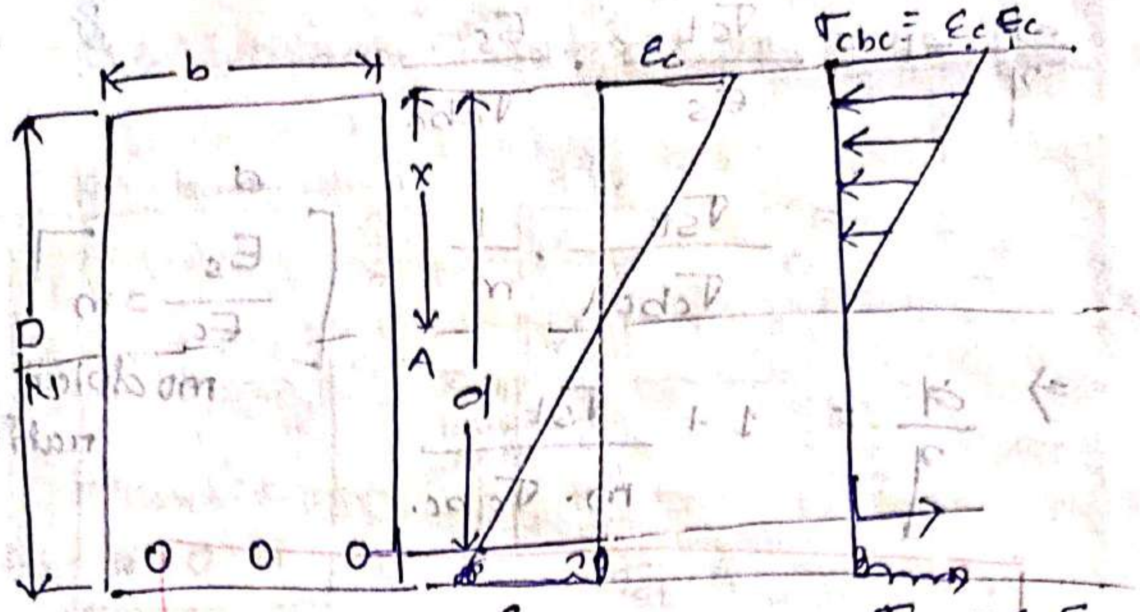
σ_{cbc} = Permissible stress in compression due to bending in concrete, in N/mm^2

POSITION OF NEUTRAL AXIS :—

Neutral axis is the axis at which the stresses are zero in the section.

The areas above and below it are subjected to compressive and tensile stresses respectively.





Rectangular section with reinforcement

Strain distribution

Stress distribution.

consider,

b = width

D = overall depth

d = effective depth

η = distance of neutral axis

ε_c = Max. Strain in concrete.

ε_s = Max. strain at the centroid of the steel

σ_{cbc} = Max. compressive stress in concrete in bending

σ_{st} = stress in steel

Since the strains in concrete and steel are proportional to their distances from the neutral axis,

$$\frac{\varepsilon_c}{\varepsilon_s} = \frac{\eta}{d-\eta}$$

$$\Rightarrow \frac{d-\eta}{\eta} = \frac{\varepsilon_s}{\varepsilon_c}$$

$$\frac{d}{\eta} - 1 = \frac{\sigma_{st}}{E_s} \cdot \frac{E_c}{\sigma_{cbc}}$$

$$= \frac{\sigma_{st}}{\sigma_{cbc}} \cdot \frac{1}{m} \qquad \left[\frac{E_s}{E_c} = m \right]$$ modular ratio

$$\Rightarrow \frac{d}{\eta} = 1 + \frac{\sigma_{st}}{m \cdot \sigma_{cbc}}$$

$$\Rightarrow \boxed{\eta = \frac{1}{1 + \frac{\sigma_{st}}{m \cdot \sigma_{cbc}}} \cdot d}$$

$$\Rightarrow \boxed{\eta = K \cdot d} \quad \Rightarrow K = \frac{1}{1 + \frac{\sigma_{st}}{m \cdot \sigma_{cbc}}}$$

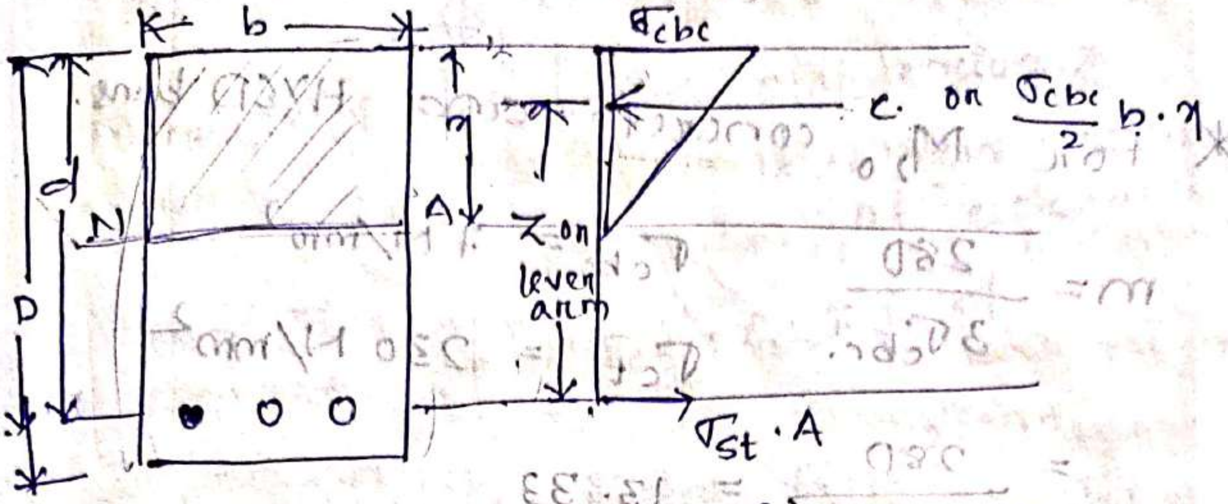
MOMENT OF RESISTANCE :-

(1) FOR BALANCED SECTION :-

When the maximum stresses in steel and concrete simultaneously reach their allowable values, the section is said to be "balanced section".

The moment of resistance shall be developed by the compressive force acting at the centroid of stress diagram on the area of concrete in compression and tensile force acting at the centroid of reinforcement multiplied by the distance between these forces.

This distance is termed as "lever arm".



Total compressive force (C) $= \frac{b \cdot x \cdot \sigma_{cbc}}{2}$

Total tensile force (T) $= \sigma_{st} \cdot As$

lever arm, $z = d - x/3$

$= d - \frac{k \cdot d}{3}$

$= d\left(1 - k/3\right)$

$= j \cdot d$

where, j = lever arm constant

Hence,
Moment of resistance (MR) =

$= \frac{b \cdot x}{2} \sigma_{cbc} \cdot jd$

$= \frac{kd \cdot j}{2} \sigma_{cbc} \, b \, d.$

$= \frac{1}{2} k \cdot j \cdot \sigma_{cbc} \cdot b \cdot d^2$

$= Q \, b \cdot d^2$

where, Q = moment of resistance constant.

* For M_{20} concrete and HYSD bars.

$$m = \frac{280}{3\sigma_{cbc}} \qquad \sigma_{cbc} = 7\ N/mm^2$$

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

$$= \frac{280}{3 \times 7} = 13.33$$

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

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

$$= 0.29$$

lever arm constant, $j = 1 - K/3$

$$= 1 - \frac{0.29}{3}$$

$$= 0.90$$

Moment of resistance constant,

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

$$= \frac{1}{2} \times 0.29 \times 0.90 \times 7$$

$$= 0.91$$

$MR = Q \cdot bd^2 = 0.91\,bd^2$

Alternatively,

Moment of resistance = Total tension × lever arm moment of resistance.

$= \sigma_{st} \cdot A_s \times j \cdot d$

$MR = \sigma_{st} \cdot A_s \cdot j \cdot d = Qbd^2$

$\Rightarrow \dfrac{A_s}{bd} = \dfrac{Q}{\sigma_{st} \cdot j}$

$= \dfrac{\frac{1}{2}\sigma_{cbc} K \cancel{j}}{\sigma_{st} \cdot \cancel{j}}$

$= \dfrac{1}{2} \cdot \dfrac{\sigma_{cbc}}{\sigma_{st}} K$

If p = percentage of steel area.

$\dfrac{A_s}{bd} \times 100$

$\dfrac{A_s}{bd} = \dfrac{1}{2} \dfrac{\sigma_{cbc}}{\sigma_{st}} K$

$\Rightarrow \dfrac{A_s}{bd} \times 100 = \dfrac{1}{2} \times \dfrac{\sigma_{cbc}}{\sigma_{st}} \times K \times 100$

$= \dfrac{\frac{1}{2} \times 7 \times 0.29 \times 100}{230}$

$= 0.4413.$

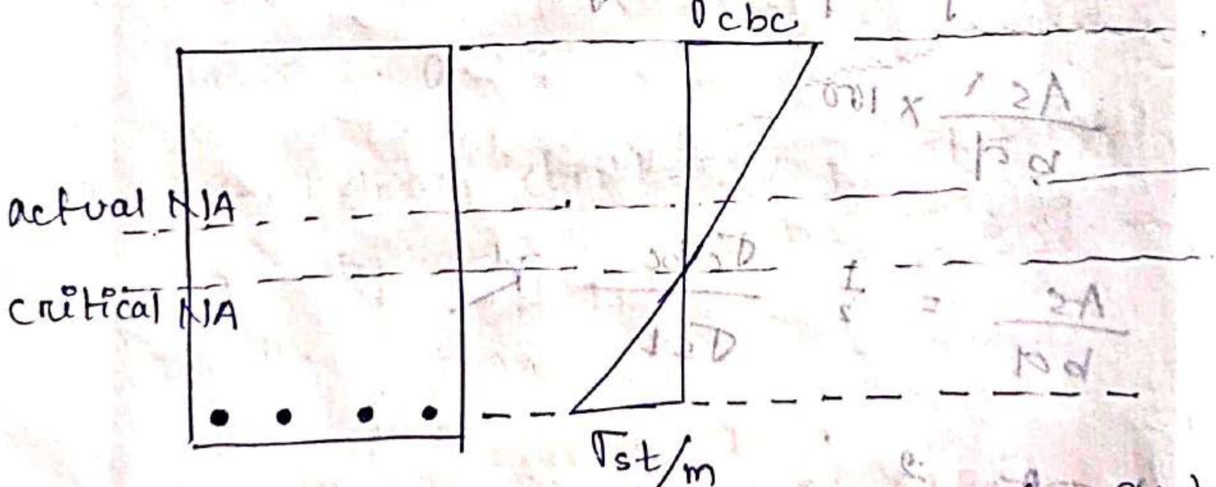
2) UNDER REINFORCED SECTION :-

When the percentage of steel in a section is less than that required for a balanced section, the section is called as "under-reinforced section".

(ii) In this ~~section~~ case, concrete stress does not reach its max. allowable value while the stress in steel reaches its max. permissible stress value.

(iii) The positions of neutral axis will shift upward, i.e. the neutral axis depth will be smaller than that in the balanced section.

(iv) The moment of resistance of such a section will be governed by allowable tensile stress in steel.



Moment of resistance = $\sigma_{st} \cdot A_s \cdot (d - x/3)$

$= \sigma_{st} \cdot A_s \cdot j' \cdot d$

[Where $j' = k'/3$

$$P = \frac{A_s \times 100}{b\,d}$$

$$MR = \sigma_{st} \cdot P \cdot \frac{b \cdot d}{100} \, j' \times d$$

$$= \frac{\sigma_{st}\, P\, j'}{100} \, bd^2$$

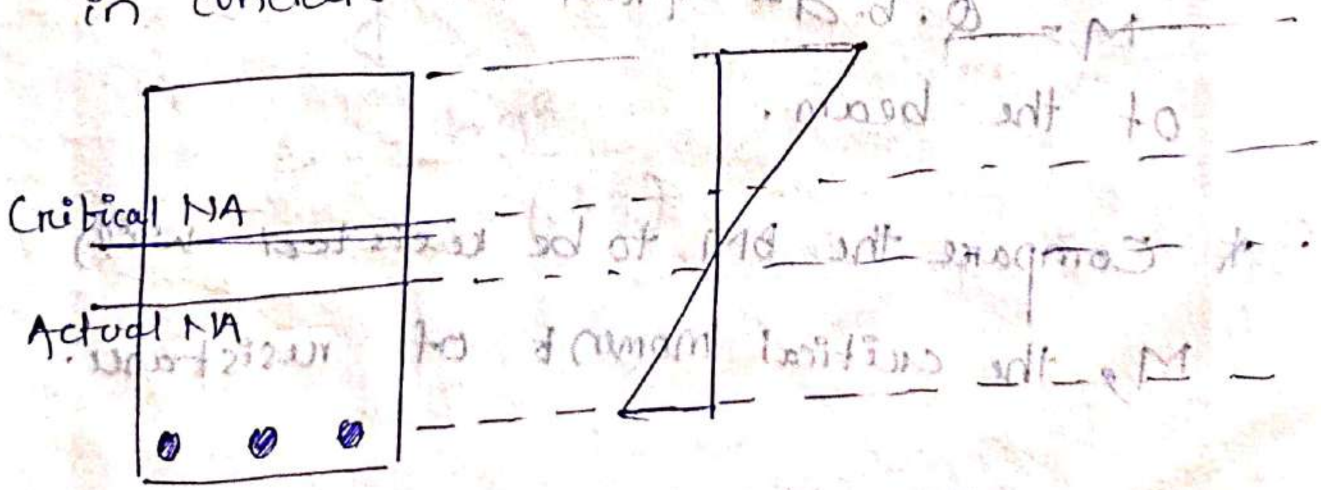
$$= Q' \cdot b \cdot d^2 \quad \left[\text{where } Q' = \frac{\sigma_{st}\, P\, j}{100}\right]$$

(3) OVER REINFORCED SECTION :-

(i) When the percentage of steel in a section is more than that required for a balanced section, the section is called "over reinforced section".

(ii) The stress in concrete reaches its max. allowable value earlier than that in steel. As the percentage steel is more, the position of the neutral axis will shift towards steel from the critical of balanced neutral axis position.

(iii) Moment of resistance of such a section will be governed by compressive stress in concrete.



$$MR = b \cdot x \cdot \sigma_{cbc} \cdot \frac{1}{2}\left(d - x/3\right)$$

$$= \frac{\sigma_{cbc}}{2} \cdot b \cdot x \cdot d\left(1 - K/3\right)$$

$$= \frac{\sigma_{cbc}}{2} \cdot b \cdot x \cdot d \cdot j'$$

$$= \frac{1}{2}\sigma_{cbc} \, K' \, j \, b d^2$$

$$\Rightarrow \boxed{MR = Q' \cdot b \cdot d^2}$$

Where, $Q' = \frac{\sigma_{cbc}}{2} \cdot K' \cdot j$

TYPES OF PROBLEMS :-

(1) Determination of area of tensile reinforcement :-

* Determine K, j, Q (Q') for the given stresses.

* Find the critical moment of resistance, $M = Q \cdot b \cdot d^2$ from the dimensions of the beam.

* Compare the BM to be resisted with M, the critical moment of resistance.

(a) If BM < M,

$M = \sigma_{st} \cdot A_s \cdot (d - x/3)$

to find A_s, in term of x, take moments of area about NA.

$b \cdot x \cdot x/2 = m \cdot A_s \cdot (d - x)$

$\Rightarrow A_s = \dfrac{b x^2}{2m(d-x)}$

* $\Rightarrow M = \dfrac{\sigma_{st}\, b x^2}{2m(d-x)} (d - x/3) =$ BM to be resisted

solve for x, and then A_s can be calculated.

(b) If BM > M

$M = \dfrac{\sigma_{cbc}}{2} \cdot b \cdot x \left(d - x/3\right) =$ BM to be resisted.

Determine x, the A_s can be obtained by taking moments of area about NA.

$A_s = \dfrac{b x^2}{2m(d-x)}$

Q. Designed a reinforced rectangular beam to resist a BM of 200 KNm. The width of the beam is to be kept 450mm. Use M20 concrete and, (i) mild steel and High strength ($\sigma_{st} = 140\ N/mm^2$) deformed bars, ($\sigma_{st} = 230\ N/mm^2$)

Ans :-

Given data,

BM = 200 KNm

b = 450 mm

f_{ck} = M20, $\sigma_{cbc} = 7\ N/mm^2$

(i) Mild steel, $\sigma_{st} = 140\ N/mm^2$

(ii) High strength deformed bars, $\sigma_{st} = 230\ N/mm^2$

modular ratio, $m = \dfrac{280}{3\sigma_{cbc}}$

$= \dfrac{280}{3 \times 7} = 13.33$

(i) For mild steel,

$$K = \frac{1}{1+\dfrac{\sigma_{st}}{m \cdot \sigma_{cbc}}} = \frac{1}{1+\dfrac{140}{13.33 \times 7}}$$

$= 0.4$

$j = 1 - K/3 = 1 - \frac{0.4}{3} = 0.87$

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

$= \frac{1}{2} \times 7 \times 0.4 \times 0.87$

$= 1.22$

$BM = Q \cdot b \cdot d^2$

$\Rightarrow 200 \times 10^6 = 1.22 \times 450 \times d^2$

$\Rightarrow d = 603.57 \simeq 605$ mm

assume,

$\phi = 20$ mm dia bar.

cover = 25 mm.

$D = d + \frac{1}{2} \cdot$ dia of bar + cover.

$= 605 + \frac{1}{2} \times 20 + 25$

$= 640$ mm.

Area of steel required, $A_s = \frac{BM}{\sigma_{st} \cdot j \cdot d}$

$= \frac{200 \times 10^2 \times 10^2}{140 \times 0.87 \times 605}$

$= 2714.10 \text{ mm}^2$

no. of bars,

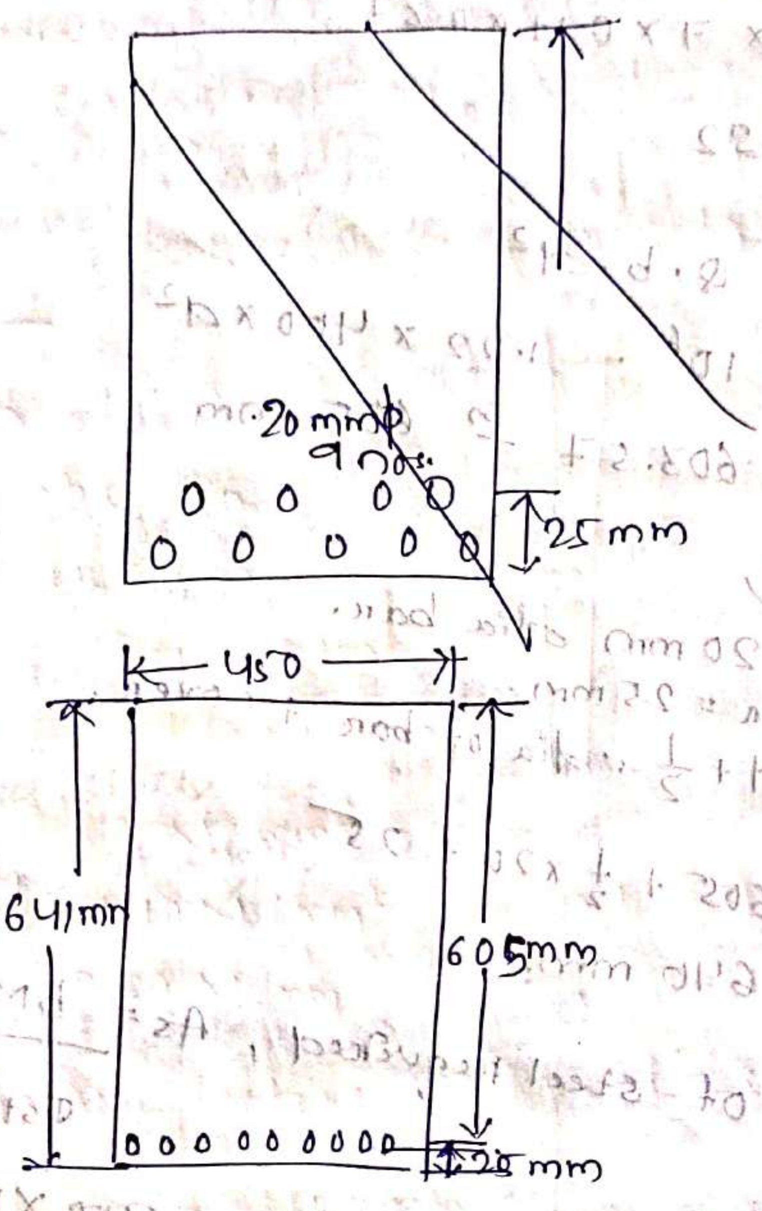
$A_{st} = \frac{\pi}{4} \times \phi^2 \times \eta$

$\Rightarrow 2714.10 = \frac{\pi}{4} \times 20^2 \times \eta$

$\Rightarrow \eta = 8.63 \simeq 9$ nos.

$\therefore$ provide 9 nos. of 20 mm dia bar

$$A_{st}\,(\text{required}) = \frac{\pi}{4} \times 20^2 \times 9$$
$$= 2827.43 \text{ mm}^2$$



(ii) High strength deformed bars :-

$$k = \frac{1}{1 + \frac{230}{7 \times 13.33}} = 0.29$$

$$j = 1 - k/3 = 1 - \frac{0.29}{3} = 0.90$$

$$Q = \frac{1}{2} \sigma_{cbc}\, k\, j = \frac{1}{2} \times 7 \times 0.29 \times 0.90$$
$$= 0.91$$

$BM = Q bd^2$

$\Rightarrow 200 \times 10^6 = 0.91 \times 450 \times d^2$

$\Rightarrow d = 698.85 \text{ mm} \simeq 700 \text{ mm}$

Assume 20 mm dia bar

clear cover = 25 mm.

$D = 700 + 10 + 25 = 735 \text{ mm.}$

Area of steel required, $A_s = \dfrac{BM}{\sigma_{st}\, j \cdot d}$

$= \dfrac{200 \times 10^6}{230 \times 0.90 \times 700}$

$= 1380.26 \text{ mm}^2$

no. of bars required

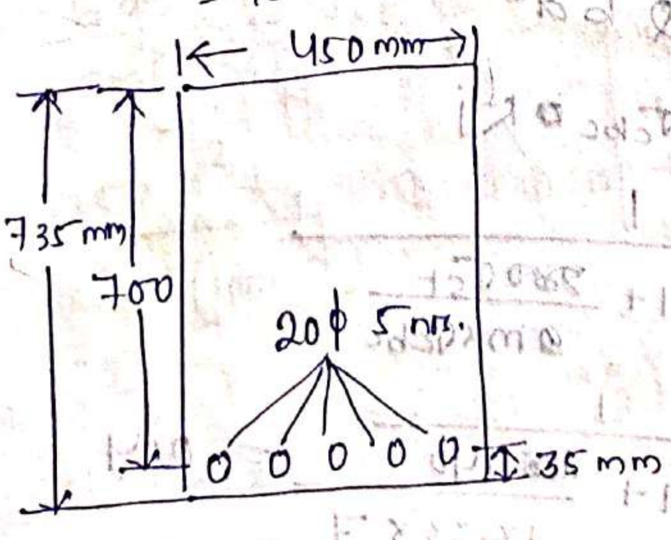
$A_s = \frac{\pi}{4} \times \phi^2 \times n$

$\Rightarrow 1380.26 = \frac{\pi}{4} \times 20^2 \times n$

$\Rightarrow n = 4.39 \simeq 5 \text{ nos.}$

$A_{s(\text{required})} = \frac{\pi}{4} \times 20^2 \times 5$

$= 1570.79 \text{ mm}^2$

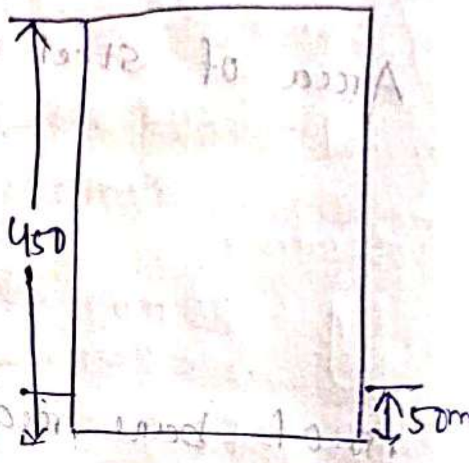


~~DT/Bf~~

Q. Determine the area of tensile rein-forcement required in a RCC beam 225 mm x 450 mm subjected to a BM of 28125 Nm. Use M_{20} and (i) Mild Steel (ii) High strength deformed bars.

Ans :-

Given data.



$b = 225$ mm

$D = 450$ mm

BM = 28125 Nm

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

$\sigma_{cbc} = 7 \; N/mm^2$

$\sigma_{st} = 140 \; N/mm^2$ for mild steel

$\sigma_{st} = 230 \; N/mm^2$ for tor steel

Assume, effective cover, $d' = 50$ mm

$d = 450 - 50 = 400$ mm.

(i) For Mild steel,

$M = Q \, b d^2$

$Q = \frac{1}{2} \sigma_{cbc} \, k j$

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

$$= \frac{1}{1 + \frac{140}{13.33 \times 7}} = 0.4$$

$j = 1 - K/3 = 0.87$

$Q = \frac{1}{2} \times 7 \times 0.4 \times 0.87$

$= 1.21$

$M = Q\, b d^2$

$= 1.21 \times 225 \times (400)^2$

$= 43560000$ Nmm

$= 43.56$ KNm. > 28.125 KNm.

∴ beam is to be designed as under-reinforced i.e. the stress in steel reaches its max. permissible value.

$M = A_{st}\, \sigma_{st} \,(d - x/3)$ ——— (1)

taking moment at compressive and tensile areas. NA.

$b \cdot x \cdot x/2 = m \cdot A_s \cdot (d - x)$

$\Rightarrow A_s = \frac{b x^2}{2m(d-x)}$

Now, substitute the value of A_s in eqn (1)

$$M = \frac{b x^2}{2m(d-x)} \sigma_{st} (d - x/3)$$

$$= \frac{225 \times x^2}{2 \times 13.33 (400 - x)} \cdot 140 \,(400 - x/3) = BM$$

$$\Rightarrow \frac{225\, x^2}{2 \times 13.33 (400 - x)} 140 \,(400 - x/3) = 28125000 \text{ Nmm}$$

$\Rightarrow x = 133.56\ mm$

$$A_s = \frac{b x^2}{2m(d-x)}$$

$$= \frac{225 \times (133.56)^2}{2 \times 13.33\,(400 - 133.56)}$$

$= 565.03\ mm^2$

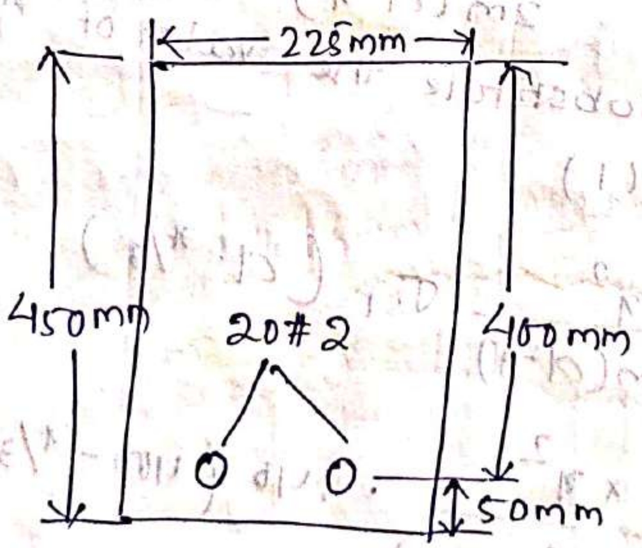
Assume $\phi = 20mm$

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

$\Rightarrow n = 1.79 \simeq 2$ nos.

$A_{s\,req} = \frac{\pi}{4} \times 20^2 \times 2$

$= 628.31\ mm^2$



(ii) For HYSD bar :-

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

$$= \frac{1}{1 + \left(\frac{230}{13.33 \times 7}\right)} = 0.28$$

$$j = 1 - K/3 = 1 - \frac{0.28}{3} = \cancel{0.90}\ 0.91$$

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

$$= 1/2 \times 7 \times 0.28 \times 0.91$$

$$= 0.89$$

$$M = Q\, b d^2 = 0.89 \times 225 \times (400)^2$$

$$= 32040000\ Nmm$$

$$= 32.04\ KNm > 28.125\ KNm$$

beam is designed as under-reinforced.

$$M = A_{st} \cdot \sigma_{st} (d - x/3) \quad \text{——— (2)}$$

∴ taking moment at compressive and tensile, NA

$$b \cdot x \cdot x/2 = m\, A_s (d - x)$$

$$\Rightarrow A_s = \frac{b x^2}{2m (d - x)}$$

put the value of A_s in eq^n (2)

$$M = A_s \sigma_{st} (d - x/3)$$

$$= \frac{b x^2}{2m(d - x)} \sigma_{st} (d - x/3) = BM$$

$$\Rightarrow \frac{225 \times x^2}{2 \times 13.33 (400 - x)} \times 230 \left(400 - x/3\right) = 2812500[illegible]$$

$\Rightarrow x = 107.83 \simeq 108\ mm$

$$\therefore A_s = \frac{b x^2}{2m(d-x)}$$

$$= \frac{225 \times (108)^2}{2 \times 13.33 \times (400-108)}$$

$$= 337.12\ mm^2$$

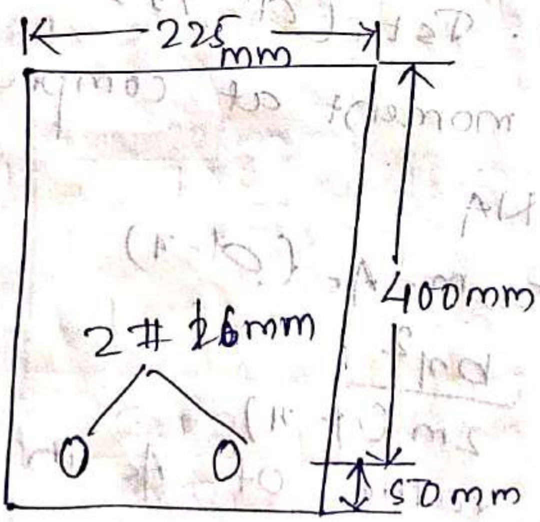
no. of bars. assume $\phi = 16mm$

$$A_s = 337.12 = \frac{\pi}{4} \times 16^2 \times n$$

$\Rightarrow n = 1.67 \simeq 2$ nos.

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

$$= 402.12\ mm^2$$



TYPE-2 :-

DESIGN OF SECTION FOR A GIVEN LOADING :-

STEPS :-

(i) Find the max. bending moment (BM) due to given loading.

(ii) Compute the constants K, j & Q for the balanced section for known stresses.

(iii) Fix the depth to breadth ratio of the beam section as 2 to 4.

(iv) From $M = Q bd^2$, find "d" and then "b" from ~~breadth~~ depth to breadth ratio.

(v) Obtain overall depth "D" by adding concrete cover to "d" the effective depth.

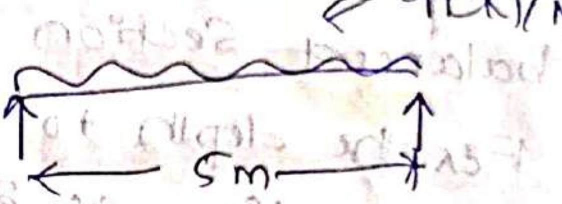
(vi) Calculate As from the relation,

$$A_s = \frac{BM}{\sigma_{st}\, j \cdot d}$$

... for the

Q. Design a simply supported rectangular beam of 5m which carries a UDL of 9 KN/m. The stresses in steel and concrete are 230 N/mm^2 and 7 N/mm^2 respectively. Assume m = 13.33.

Ans:-



Given data,

$L = 5\,m$

$w = 9\,KN/m$

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

$\sigma_{cbc} = 7\,N/mm^2$

$m = 13.33$

assume, $\frac{d}{b} = 2 \Rightarrow d = 2b \Rightarrow b = \frac{d}{2}$

$$BM = \frac{wl^2}{8} = \frac{9 \times 5^2}{8} = 28.125\ KNm$$

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

$$= \frac{1}{1 + \frac{230}{13.33 \times 7}} = 0.29$$

$j = 1 - k/3 = 1 - \frac{0.29}{3} = 0.90$

$Q = \frac{\sigma_{cbc}}{2} k j$

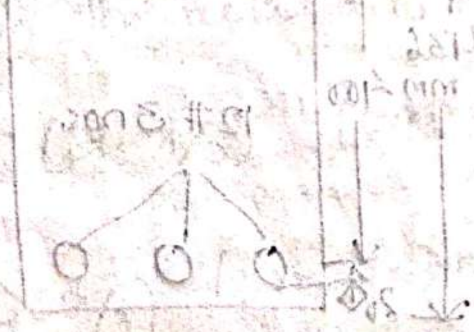
$= \frac{1}{2} \times 7 \times 0.29 \times 0.90$

$= 0.91$

Moment of resistance, $M = Qbd^2$

$\Rightarrow 28.125 \times 10^6 = 0.91 \times \frac{d}{2} \times d^2$

$\Rightarrow d = 395.39 \simeq 400$ mm



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

$\Rightarrow \frac{400}{b} = 2$

$\Rightarrow b = 200$ mm

assume, $\phi = 12$ mm

$cc = 30$ mm

$D = 400 + \frac{\phi}{2} + 30$

$= 400 + \frac{12}{2} + 30$

$= 436$ mm

$A_s = \frac{BM}{\sigma_{st}\, j\, d}$

$= \frac{28.125 \times 10^6}{230 \times 0.90 \times 400}$

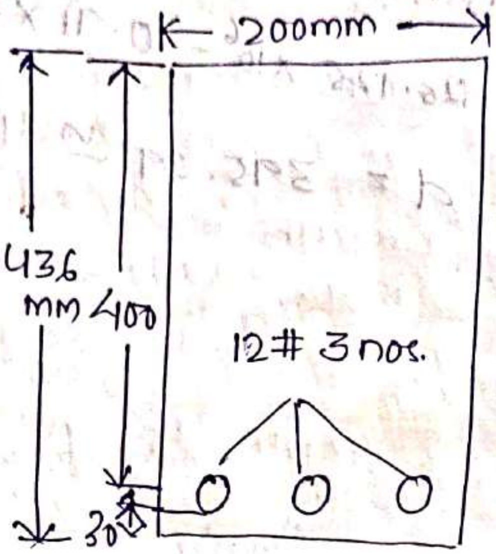
$= 339.67$ mm^2

no. of bars,

$A_s = \frac{\pi}{4} \times 12^2 \times n$

$\Rightarrow 339.67 = \frac{\pi}{4} \times 12^2 \times n$

$\Rightarrow n = 3$ nos.



TYPE - 3 :-

TO DETERMINE THE LOAD CARRYING CAPACITY OF A GIVEN BEAM :-

Given :-

The dimenssions of the beam section, the material stresses and area of reinforcing steel.

STEPS :-

(i) Find the position of the neutral axis from section and reinforcement given.

(ii) Find the position of the critical NA from known permissible stresses of concrete and steel.

$$x = \frac{1}{1 + \frac{\sigma_{st}}{\sigma_{cbc}\, m}} \cdot d$$

(iii) check if,

(a) (i) > (ii) the Section is over reinforced

(b) (i) < (ii) the Section is under reinforced.

(iv) Calculate M from the relation,

$$M = b\, x \tfrac{1}{2} \sigma_{cbc} (d - x/3)$$ (over reinforced)

OR

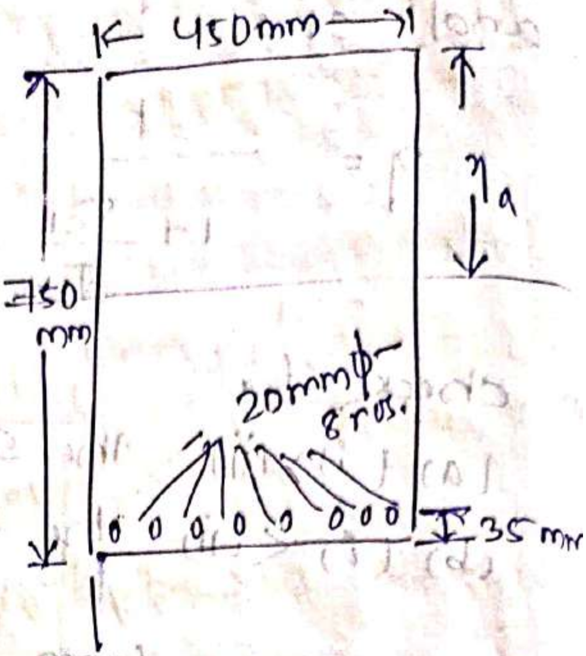
$$M = \sigma_{st} A_s (d - x/3)$$ (under-reinforced)

(v) If the effective span and the support conditions of the beam are known, the load carrying capacity can be computed.

Q. Find the moment of resistance of the RCC beam, Section, 450mm x 750mm, if the stresses in steel and concrete are not to exceed 230 N/mm^2 and 7N/mm^2 respectively. m = 13.33 and also compute the maximum Super imposed load of the section can carry if the effective span of the beam is 5m and is simply supported at its ends.

Soln :-

Given data,



$b = 450mm$

$D = 750mm$

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

$\sigma_{cbc} = 7 N/mm^2$

$m = 13.33$

$l = 5m.$

$A_s = 20\phi - 8$

Let x_a = depth of actual NA.

Taking moments of compressive and tensile area about NA.

$$\frac{b x_a^2}{2} = m A_s (d - x_a)$$

$$\Rightarrow \frac{450 \times x_a^2}{2} = 13.33 \times \frac{\pi}{4} \times 20^2 \times 8 \, (715 - x_a)$$

$$\Rightarrow x_a = 260.22mm$$

Depth of critical NA $= \dfrac{1}{1 + \dfrac{\sigma_{st}}{m\,\sigma_{cbc}}} d$

$$= \frac{1}{1 + \frac{230}{13.33 \times 7}} \times 715$$

$$= 206.35 mm$$

$\because 260.22 > 206.35$

$x_a > x_{ca}$

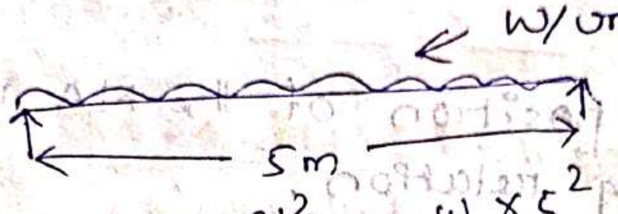
∴ the Section is over-reinforced.

$$MR = b\, x_a \frac{\sigma_{cbc}}{2}\left(d - \frac{x_a}{3}\right)$$

$$= 450 \times 260.22 \times \frac{7}{2}\left(0.715 - \frac{260.22}{3}\right)$$

$$= 257490162.1 \text{ Nmm}$$

$$= 257.49 \text{ KNm.}$$



$$\text{Max BM} = \frac{wl^2}{8} = \frac{w \times 5^2}{8}$$

$$MR = BM$$

$$\Rightarrow 257.49 \times 10^3 = \frac{w \times 5^2}{8}$$

$$\Rightarrow w = 82396.8 \text{ N/m.}$$

Unit wt. of reinforced cement concrete, $= 25 \text{ KN/m}^3$

Self wt. of beam per meter length

$$= 450 \times 10^{-3} \times 750 \times 10^{-3} \times 25 \times 10^3$$

$$= 8437.5 \text{ N/m}$$

Total super imposed load which the beam can carry excluding self weight

$$= 82396.8 - 8437.5$$

$$= 73959.3 \text{ N/m.}$$

TYPE-4 :-

TO CHECK THE STRESSES DEVELOPED IN CONCRETE AND STEEL :-

Given :-

The Section, reinforcement and bending moment are given.

STEPS :-

(1) Find the position of the NA using the following relation.

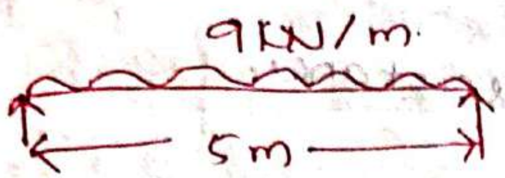
$$b\frac{x^2}{2} = m A_s (d - x)$$

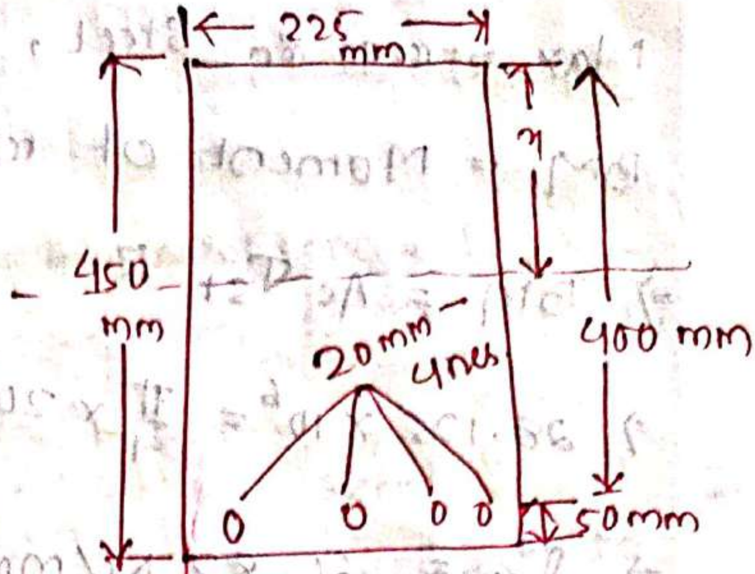
(2) Determine lever arm, $z = d - x/3$

(3) $BM = \sigma_{st} A_s z$ is used to find out the actual stress in steel σ_{st}.

(4) To compute the actual stress in concrete σ_{cbc}, use the following relation. $BM = \frac{\sigma_{cbc}}{2} b\, x\, z$.

Q. A rectangular beam 225 mm x 450 mm is simply supported over a span of 5m. it is provided with 4 nos. 20 mm dia. HYSD bars as reinforcement. Calculate the max. Stresses developed in steel and concrete if the beam carries a UDL of 9 kN/m including the self weight of beam, m = 13.





Soln :-

$$BM = \frac{wl^2}{8}$$

$$= \frac{9 \times 5^2}{8}$$

$$= 28.125 \text{ KNm.}$$

Let "x" be the depth of NA from the top concrete fibre, Taking moment of compressive and tensile areas about NA.

$$b\frac{x^2}{2} = m A_{st}(d - x)$$

$$\Rightarrow 225 \times \frac{x^2}{2} = 13 \times \frac{\pi}{4} \times 20^2 \times 4 \times (400 - x)$$

$$\Rightarrow x = 179.10 \simeq 180 \text{ mm.}$$

lever arm, $z = d - x/3$

$$= 400 - \frac{180}{3}$$

$$= 340 \text{ mm}$$

Max. stress in concrete,

$$BM = b \cdot x \cdot \frac{\sigma_{cbc}}{2} \times z$$

$$\Rightarrow 28.125 \times 10^6 = 225 \times 180 \times \frac{\sigma_{cbc}}{2} \times 340$$

$$\Rightarrow \sigma_{cbc} = 4.08 \text{ N/mm}^2$$

Max. stress in steel,

BM = Moment of resistance.

$\Rightarrow BM = A_s \sigma_{st} z$

$\Rightarrow 28.125 \times 10^6 = \frac{\pi}{4} \times 20^2 \times 4 \times \sigma_{st} \times 340$

$\Rightarrow \sigma_{st} = 65.82 \ N/mm^2$

GRADE OF CONCRETE :-

	CEMENT	SAND	AGGRIGATE
M_5	1	5	10
$M_{7.5}$	1	4	8
M_{10}	1	3	6
M_{15}	1	2	4
M_{20}	1	1.5	3
M_{25}	1	1	2

PROPERTIES OF CONCRETE :-

1. Increase strength with age
2. Tensile strength of concrete

$$\boxed{F_{cr} = 0.7\sqrt{F_{ck}}}$$

3. Elastic deformation

$$\boxed{E_c = 5000\sqrt{F_{ck}}}$$

4. Shrinkage

$\boxed{\text{Value} - 0.0003}$

5. Creep

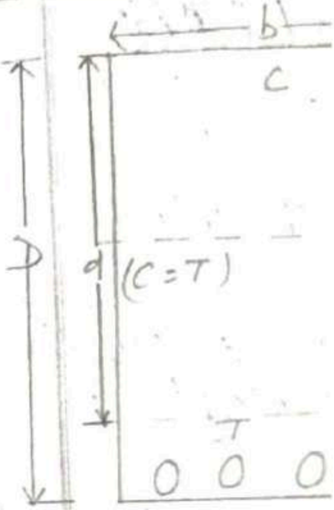
Age of Loading	creep co.efficient
7 days	2.2
28 days	1.6
1 year	1.1

(e)

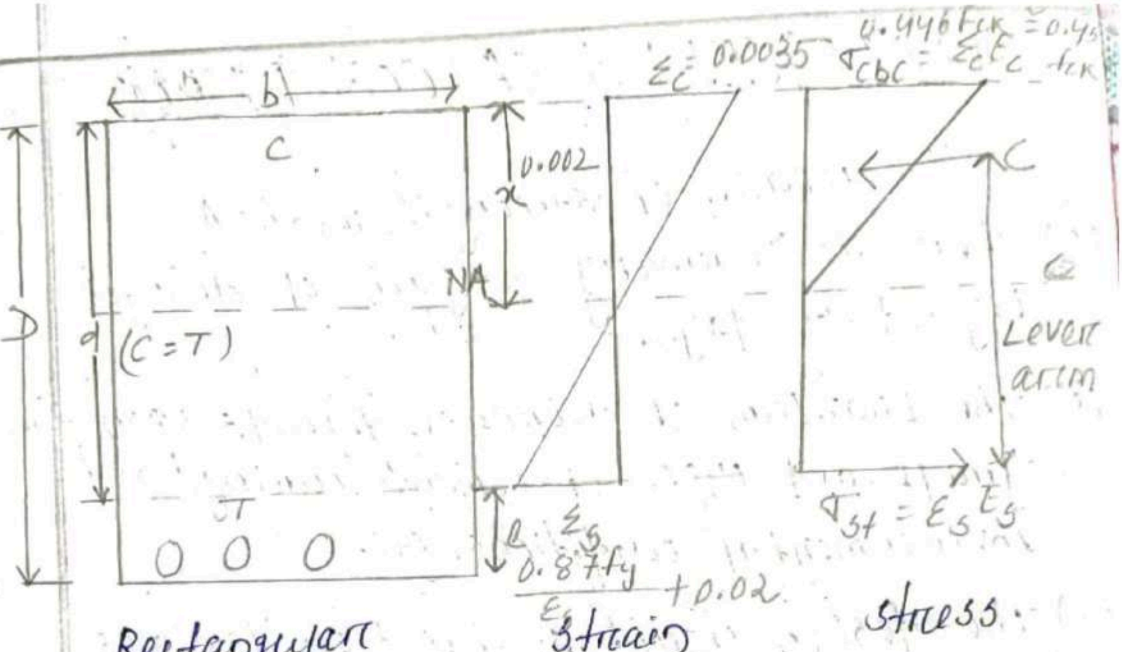
Type of Aggregate	co-efficient of thermal expansion
Quartzite	1.2 to 1.3×10^{-5}
sandstone	0.9 to 1.2×10^{-5}
Granite	0.7 to 0.95×10^{-5}
Balast	0.8 to 0.95×10^{-5}
Lime stone	0.6 to 0.9×10^{-5}

RCC DESIGN :-

1. working stress Method (WSM)
2. Ultimate load Method (ULM) or Load Factor Method (LFM)
3. Limit state Method (LSM)
4. Performance Design Method



Rectangula
section wi
Reinforceme
where,
b = widt
D = ove
d = eff
x = Di
ε_s = Ma
ε_c = S
e = ef
e' = cl
σ_{cbc} =
σ_{st} = S



Rectangular section with Reinforcement

Strain

stress.

where,

b = width

D = overall Depth

d = effective depth

x = Distance of NA

ε_s = Max^m strain in steel

ε_c = strain in concrete

e = effective depth

e' = clear cover

σ_{cbc} = Permissible stress in concrete in bending

σ_{st} = stress in steel in tension

PROPERTIES OF CONCRETE:

Increase of strength with Age-

i) There is Normally a gain of strength beyond 28 days.

ii) The quantum of increase depends upon the grade and type of cement, curing and environmental conditions, etc.

iii) The design should be based on 28 days characteristic strength of concrete unless there is a evidence to justify a higher strength for a particular structure due to age

The characteristic strength is defined as the strength of material below which not more than 5 percent of the test results results are expected to fall.

(4)

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structure due to

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below which not
the test results
ru.

WORKING STRESS METHOD	LIMIT STATE METHOD
1. The stresses in an element is obtained from the working loads and compared with permissible stresses.	1. the stressess are obtained from design loads and compared with design strength
2. The Method follows linear stress-strain behaviour of both the materials.	2. In this method, it follows linear strain relationship but not linear stress relation.
3. Modular ratio can be used to determine allowable stresses.	3. the ultimate stress of material it self are used as allowable stress
4. Material capabilities are under estimated to large extent factor of safety are used in WSM.	4. The material capabilities are not under estimated as much as they are in working stress method partial safety factors are used in limit state method.
5. the member is considered as working stress.	
6. ultimate load carrying capacity can't be predicted accurately.	

LSM :-

Service + strength

FOS
steel - 1.15
concrete - 1.5

1. Limit state of collapse
2. Limit state of serviceabity

$$\frac{F_{ck}}{1.5} = \frac{1}{1.5} = 0.67\ f_{ck}$$

$$= \frac{0.67}{1.5} = 0.45\ f_{ck} \cong 0.446 f_{ck}$$

$$f_y = \frac{f_y}{1.15} = 0.87 f_y$$

LIMIT STATE METHOD :-

(i) Limit states are the acceptable limits for the safety and serviceability requirements of the structure before failure occour.

(ii) The design of structure by this method will thus ensure that they will not reach limit state and will not become unfit for the use for which they are intended.

(iii) It is worth mentioning that structure will not just fail or collapse by violating the limit states, failure, there fore implies that clearly define limit state of structural usefullness has been exceeded.

LIMIT STATE OF COLLAPSE :-

(i) Limit state of collapse deals with the strength and stability of structure subjected to the max. design loads out of the possible combination of several types of loads.

(ii) Therefore, this limit state ensures that neither any part nor the whole structure should collapse or become unstable under any combination of expected overloads.

(iii) Factors considered are shear, flexure, torsion compression.

LIMIT STATE OF SERVICEABLITY :-

Limit state of serviceability deals with deflected and cracking of structure under service load, durability under working environment during their anticipated exposure conditions during service, stability of structure as a whole, fire resistance, cracking, deflection etc.

UNDER REINFORCED SECTION :-

(i) The under reinforced section failure occours due to the failurs of steel as the steel achiers its max. permissible stress prior to concrete.

(ii) The concrete is under stressed.

(iii) The failure shall be a ductile failure.

(iv) In gives sufficient warning before failure. Therefore this kind of a section is always desirable.

OVER REINFORCED SECTION :-

(i) The Failure of this section is due to failure of concrete.

(ii) As concrete achieves its max. permissible strength Prior to steel at the time to failure.

(iii) This kind of section is always avoided because it indicates or provides a brittle failure.

(iv) The brittle failure is always without warning, therefore such kind of a section ~~white~~ which has brittle failure and high moment of resistance capacity is of no use.

Analysis of singly reinforced section :-

(1) Actual depth of NA (x_a) :-

(i) It is depth of NA which divides the overall section in compression and tension.

(ii) It is the depth that tells overall failure a due to concrete or steel or both.

(iii) It is depth of neutral axis which may be calculated by equating the moment of area of compression and tension.

$$b \times x_a \times \frac{x_a}{2} = 0.87 f_y A_{st} (d-x)$$

(2) CRI

(i) It
fail
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(ii) This
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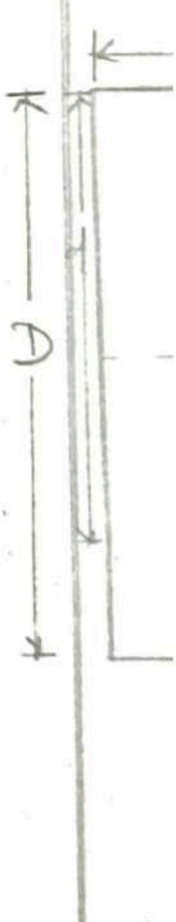


(2) CRITICAL DEPTH OF NA (x_c):-

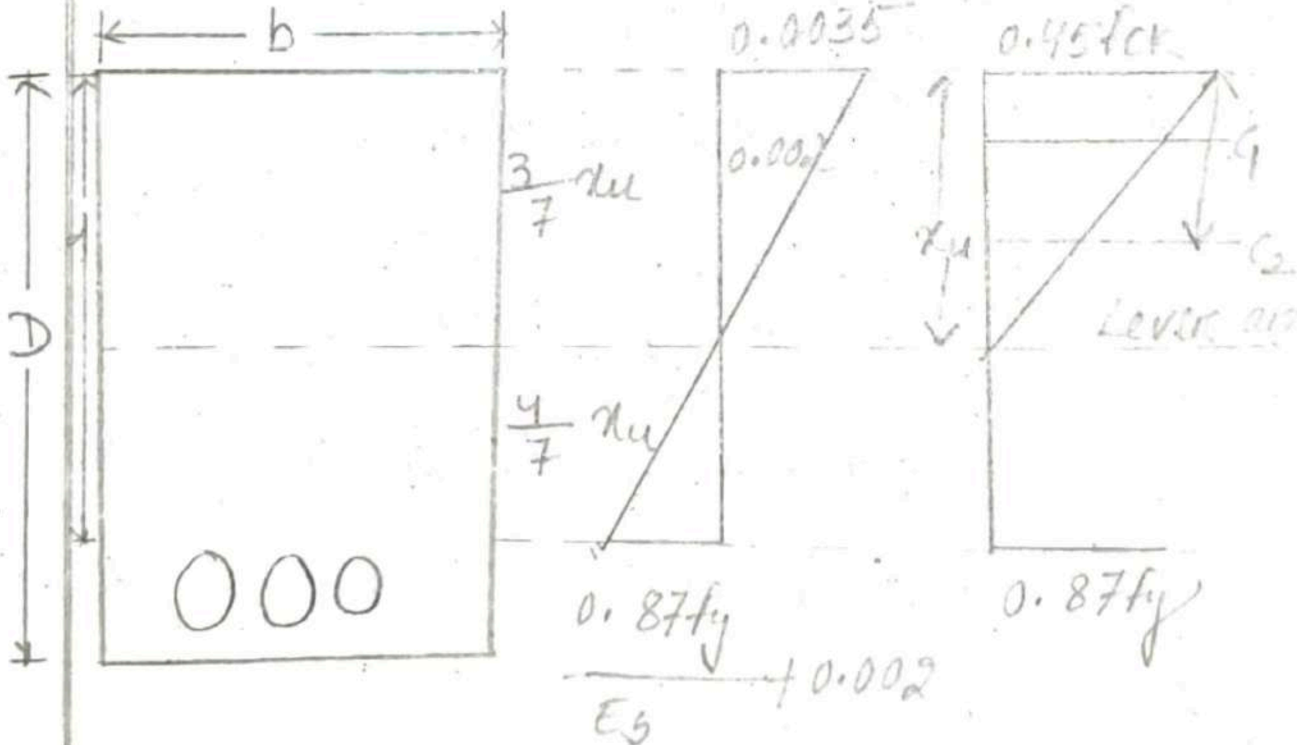
(i) It is the depth when steel and concrete fails simultaneously at that time overall structure fails.

(ii) This is the depth in which variation can not exist therefore it is also called as ideal depth of NA.

$x_a < x_c$ = under reinforced section

$x_a = x_c$ = Balanced section

$x_a > x_c$ = over reinforced section



$$\frac{x_u}{0.0035} = \frac{x_1}{0.002}$$

$\Rightarrow x_1 = \frac{4}{7} x_u$

$x_2 = x_u - x_1$

$\Rightarrow x_2 = x_u - \frac{4}{7} x_u$

$\Rightarrow x_2 = \frac{3}{7} x_u$

moment of resistance from compressive force

$MR = C \times$ lever arm

$C = C_1 + C_2$

$C_1 = 0.45 f_{ck} \times \frac{3}{7} x_u \times B$

$= 0.192 f_{ck} x_u B$

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

$= 0.171 x_u B f_{ck}$

$C = C_1 + C_2$

$C = 0.192 f_{ck} x_u B + 0.171 x_u B f_{ck}$

$= 0.363 f_{ck} x_u B$

lever arm :-

$$\bar{y} = \frac{C_1 \bar{y}_1 + C_2 \bar{y}_2}{C_1 + C_2}$$

$y_1 = \frac{1}{2} \times \frac{3}{7} x_u = 0.214 x_u$

$$y_2 = \frac{3}{7} x_u + \left(\frac{3}{8} \times \frac{4}{7} x_u \right)$$
$$= 0.642 x_u$$

$$\bar{y} = \frac{0.192 f_{ck} x_u B \times 0.214 x_u + 0.171 x_u B f_{ck} \times 0.6}{0.36 f_{ck} x_u B}$$

$$= \frac{0.041 f_{ck} x_u B + 0.109 f_{ck} x_u B}{0.36 f_{ck} x_u B}$$

$$= \frac{f_{ck} x_u B (0.15)}{f_{ck} x_u B (0.36)}$$

$$= 0.42$$

Lever arm $= d - 0.42 x_u$

$MR = 0.36 f_{ck} x_u B \times (d - 0.42 x_u)$

Actual depth of NA

$C = T$

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

$$\boxed{\Rightarrow x_u = \frac{0.87 f_y A_{st}}{0.36 f_{ck} B}}$$ (page 10 - 9.6)

Critical depth of NA :-

$$\Rightarrow \frac{0.0035}{x_u \lim} = \frac{\frac{0.87 f_y}{E_s} + 0.002}{d - x_u \lim}$$

$$\Rightarrow \frac{d - x_u \lim}{x_u \lim} = \frac{\frac{0.87 f_y}{E_s} + 0.002}{0.0035}$$

$$\Rightarrow \frac{d}{x_{u}\,lim} - 1 = \frac{0.87f_y}{E_s} + \frac{0.002}{0.0035}$$

$$\Rightarrow \frac{d}{x_{u}\,lim} = \frac{\frac{0.87f_y}{E_s} + 0.002}{0.0035} + 1$$

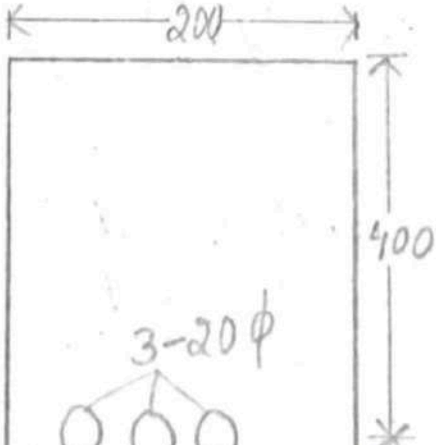
$$\Rightarrow x_u\,lim = \left(\frac{\frac{0.87f_y}{E_s} + 0.002}{0.0035} + 1\right) d$$

$$\Rightarrow x_u\,lim = kd$$

f_y	$x_{u,max}/d$
250	0.53
415	0.48
500	0.46

Problem - 1

Determine depth of neutral axis for the section.



(i) $f_{ck} = 15\ N/mm^2$, $f_y = 250\ N/mm^2$

(ii) $f_{ck} = 20\ N/mm^2$, $f_y = 415\ N/mm^2$

Given data

$b = 200\,mm$

$D = 450\,mm$

$e = 50\,mm$

$d = 400\,mm$

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

$f_y = 250\,N/mm^2$

(i) $A_{st} = \frac{\pi}{4} \times (20)^2 \times 3$

$= 942.47\,mm^2$

$C = 0.36 f_{ck}\, x_u\, b$

$= 0.36 \times 15 \times x_u \times 200$

$T = 0.87 f_y A_{st}$

$= 0.87 \times 250 \times 942.47$

$= 204987.225\,\cancel{mm^2}\,N$

$C = T$

$\Rightarrow 0.36 \times 15 \times x_u \times 200 = 204987.225$

$\Rightarrow x_u = \frac{204987.225}{0.36 \times 15 \times 200}$

$\Rightarrow x_u = 190\,mm$

$x_{u\,lim} = 0.53\,d$

$= 0.53 \times 400$

$= 212\,mm$

$x_u < x_{u\,lim}$

Hence it is under reinforced section.

(ii) $F_{ck} = 20 \ N/mm^2$

$f_y = 415 \ N/mm^2$

$A_{st} = \frac{\pi}{4} \times (20)^2 \times 3$

$= 942.47 mm^2$

$C = 0.36 \times 20 \times x_u \times 200 \ N$

$T = 0.87 \times 415 \times 942.47$

$= 340278.79 \ N$

$C = T$

$0.36 \times 20 \times x_u \times 200 = 340278.79$

$\Rightarrow x_u = \dfrac{340278.79}{0.36 \times 20 \times 200}$

$\Rightarrow x_u = 236 \ mm$

$x_{ulim} = 0.48 d$

$= 0.48 \times 400$

$= 192 \ mm$

$x_u > x_{ulim}$

Hence it is over reinforced section.

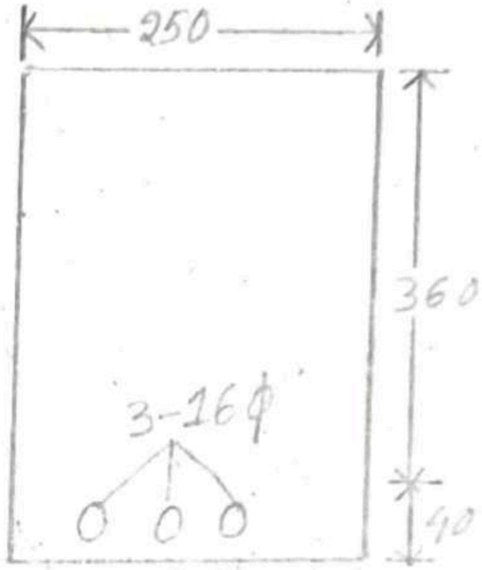
Problem-2

Determine the lever arm for section shown in fig if effective cover = 40mm, and

(i) $f_{ck} = 20 N/mm^2$, $f_y = 250 N/mm^2$

(ii) $f_{ck} = 25 N/mm^2$, $f_y = 415 N/mm^2$

Given data :-



$b = 250mm$

$d = 360mm$

$e = 40mm$

(i) $A_{st} = \frac{\pi}{4} \times (16)^2 \times 3$

$= 603.18 \ mm^2$

$C = 0.36 f_{ck} \ x_u b$

$= 0.36 \times 20 \times x_u \times 250 \ N$

$T = 0.87 f_y A_{st}$

$= 0.87 \times 250 \times 603.18 \ N$

$C = T$

$0.36 \times 20 \times x_u \times 250 = 0.87 \times 250 \times 603.18$

$\Rightarrow x_u = 72.88mm$

$x_{u lim} = 0.53 d = 0.53 \times 360 = 190.8mm$

$x_u < x_{u lim}$ (under reinforced section)

Lever arm $= d - 0.42 x_u$

$= 360 - 0.42 \times 72.88$

$= 329.39 \ mm$

i) $A_{st} = \frac{\pi}{4}(16)^2 \times 3$

$= 603.18 mm^2$

$C = 0.36 f_{ck} x_u b$

$= 0.36 \times 25 \times x_u \times 250$ N

$T = 0.87 f_y A_{st}$

$= 0.87 \times 415 \times 603.18$ N

$C = T$

$0.36 \times 25 \times x_u \times 250 = 0.87 \times 415 \times 603.18$

$\Rightarrow x_u = 96.79 mm$

$x_{ulim} = 0.48d = 0.48 \times 360 = 172.8 mm$

$x_u < x_{ulim}$ (under reinforced section)

Lever arm $= \cancel{0.42}\ d - 0.42 x_u$

$= 360 - 0.42 \times 76.79$

$= \cancel{327.74 mm}$

$= 319.34 mm$

Problem-3

Determine the lever arm for section shown in fig if effective cover = 50 mm.

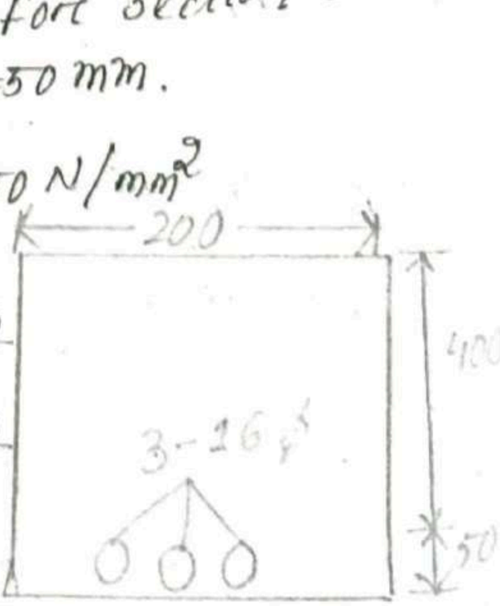
$f_{ck} = 15 N/mm^2$, $f_y = 250 N/mm^2$

Given data

$b = 200 mm$ $f_{ck} = 15 N/mm^2$

$d = 400 mm$ $f_y = 250 N/mm^2$

$e = 50$



$A_{st} = \frac{\pi}{4} \times (16)^2 \times 3$
$= 603.18\ mm^2$

$C = 0.36\ f_{ck}\ x_u\ b$
$= 0.36 \times 15 \times x_u \times 200\ N$

$T = 0.87\ f_y\ A_{st}$
$= 0.87 \times 250 \times 603.18$

$C = T$
$0.36 \times 15 \times x_u \times 200 = 0.87 \times 250 \times 603.18$
$\Rightarrow x_u = 121.47\ mm$
$x_{u\,lim} = 0.53d = 0.53 \times 400 = 212\ mm^2$

$x_u < x_{u\,lim}$ (over reinforced section)

Lever arm $= d - 0.42\,x_u$
$= 400 - 0.42 \times 121.47$
$= 348.98\ mm$

Problem-4

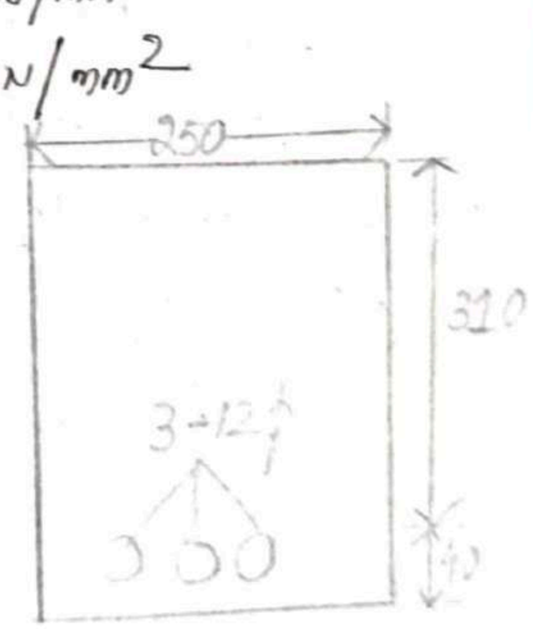
Determine the moment of resistance for the fig

(i) $f_{ck} = 20\ N/mm^2$, $f_y = 415\ N/mm^2$

(ii) $f_{ck} = 20\ N/mm^2$, $f_y = 500\ N/mm^2$

Given data:-

$b = 250\ mm$
$d = 310\ mm$
$c = 40\ mm$



$A_{st} = \frac{\pi}{4} \times (12)^2 \times 3$

$= 339.29 mm$

$C = 0.36 f_{ck} x_u b$

$= 0.36 \times 20 \times x_u \times 250$ N

$T = 0.87 f_y A_{st}$

$= 0.87 \times 415 \times 339.29$ N

$C = T$

$\Rightarrow 0.36 \times 20 \times x_u \times 250 = 0.87 \times 415 \times 339.29$

$\Rightarrow x_u = 68.05 mm$

$x_{ulim} = 0.48d = 0.48 \times 310 = 148.8 mm$

$x_u < x_{ulim}$ (over reinforced section)

Lever arm =

$= d - 0.42 x_u$

$= 310 - 0.42 \times 68.05$

$= 281.41 mm$

$C = 0.36 f_{ck} x_u b$

$= 0.36 \times 20 \times 68.05 \times 250$

$= 122490$ N

$MR = C \times$ Lever arm

$= 122490 \times 281.41$

$= 34469910.9$ Nmm

$= 34.46$ KNm

(18)

$\times 339.29$

$= 148.8\,mm$

section)

(ii) $A_{st} = \frac{\pi}{4} \times (12)^2 \times 3$

$= 339.29\,mm$

$C = 0.36 f_{ck} x_u b$

$= 0.36 \times 20 \times x_u \times 250\ N$

$T = 0.87 f_y A_{st}$

$= 0.87 \times 500 \times 339.29$

$C = T$

$\Rightarrow 0.36 \times 20 \times x_u \times 250 = 0.87 \times 500 \times 339.29$

$\Rightarrow x_u = 81.99\,mm$

$x_{ulim} = 0.46\,d = 0.46 \times 310 = 142.6\,mm$

$x_u < x_{ulim}$ (over reinforced section).

Lever arm $= d - 0.42\,x_u$

$= 310 - 0.42 \times 81.99$

$= 275.56\,mm$

$C = 0.36 f_{ck} x_u b$

$= 0.36 \times 20 \times 81.99 \times 250$

$= 147582\,N$

$M_R = C \times$ Lever arm

$= 147582 \times 275.56$

$= 40667695.92\,Nmm$

$= 40.66\,kNm$

Simply supported Beam:-

(i) $e = L_c + d$

(ii) e = c/c distance between supported

continuous Beam:-

$t_s \leq L_c/12$

$e = L_c + d$

e = c/c distance between support

$t_s \geq \frac{L_c}{12}$

$e = L_c + 0.5d$

$e = L_c + 0.5t_s$

Problem:-

Design a rectangular beam to resist a BM eq to 75 kNm.

(i) M_{25} mix and Fe 415 grade of steel

(ii) M_{25} mix and Fe 550 grade of steel

Given data

(i) $F_{ck} = 25\ N/mm^2$

$f_y = 415\ N/mm^2$

$BM = 75\ kNm$

Factored BM $= 1.5 \times 75 = 112.5$ kNm

$MR = 0.36 f_{ck}\, b\, x_u (d - 0.42 x_u)$

Assume

$$\frac{D}{b} = 1.5 \simeq \frac{d}{b} = 1.5$$

$$\Rightarrow b = \frac{d}{1.5}$$

$MR = 0.36 f_{ck}\ 0.48d \times \frac{d}{1.5}(d - 0.42 \times 0.48d)$

$\Rightarrow 112.5 \times 10^6 = 0.36 \times 25 \times 0.48d \times \frac{d}{1.5}(d - 0.42 \times 0.48d)$

$\Rightarrow d = 365.74\ mm \simeq 365mm$

Assume,

$e = 35$

$D = d + e$

$= 365 + 35$

$= 400mm$

$b = \frac{d}{1.5} = \frac{365}{1.5} = 243.33\ mm \simeq 300mm$

$MR = 0.87 f_y A_{st}(d - 0.42 x_u)$

$\Rightarrow 112.5 \times 10^6 = 0.87 \times 415 \times A_{st} \times (365 - 0.42 \times 0.48 \times 365)$

$\Rightarrow A_{st} = 1300\ mm^2$

Assume,

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

$\Rightarrow 1300 = \frac{\pi}{4} \times (20)^2 \times x$

$\Rightarrow x = 4$ nos.

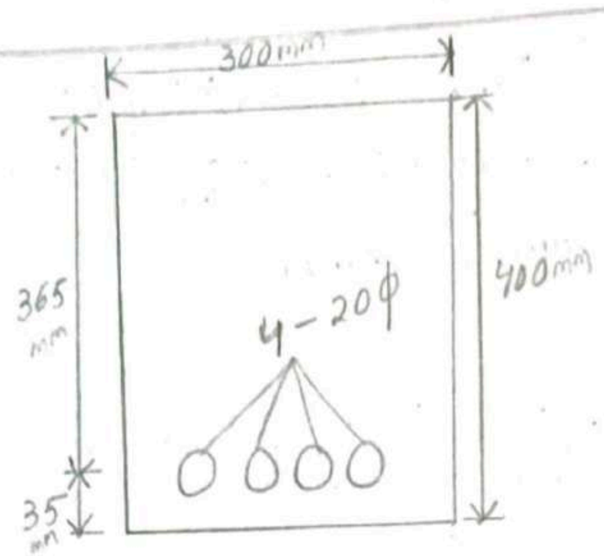
A_{st} min $\Rightarrow \frac{A_{st}}{bd} = \frac{0.85}{f_y}$

$\Rightarrow \frac{A_{st}}{300 \times 365} = \frac{0.85}{415}$

$\Rightarrow A_{st} = 224.55\ mm^2 \simeq 230\ mm^2$

A_{st} max $\Rightarrow 0.04bD = 0.04 \times 300 \times 400$

$= 4800\ mm^2$



(ii) Given data :-

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

$f_y = 550\ N/mm^2$

$BM = 75\ kNm$

Factored $BM = 1.5 \times 75 = 112.5\ kNm$

$MR = 0.36 f_{ck}\, b\, x_u (d - 0.42 x_u)$

$\Rightarrow 112.5 \times 10^6 = 0.36 \times 25 \times \frac{d}{1.5} \times 0.443 d \times (d - 0.42 \times 0.443 d)$

$\Rightarrow d = 375\ mm$

Assume,

$e = 25\ mm$

$D = e + d = 25 + 375 = 400\ mm$

$b = \frac{D}{1.5} = \frac{400}{1.5} = 265\ mm \cong 300\ mm$

$MR = 0.87 f_y A_{st} (d - 0.42 x_u)$

$\Rightarrow 112.5 \times 10^6 = 0.87 \times 550 \times A_{st} \times (375 - 0.42 \times 0.44 \times 375)$

$\Rightarrow A_{st} =$

Assume

$A_{st} = \frac{\pi}{4}$

$\Rightarrow 770 =$

$\Rightarrow x =$

A_{st} mi

A_{st} mi

$\Rightarrow A_{st} = 770\, mm^2$

Assume.

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

$\Rightarrow 770 = \frac{\pi}{4} \times (20)^2 \times x$

$\Rightarrow x = 3$ nos.

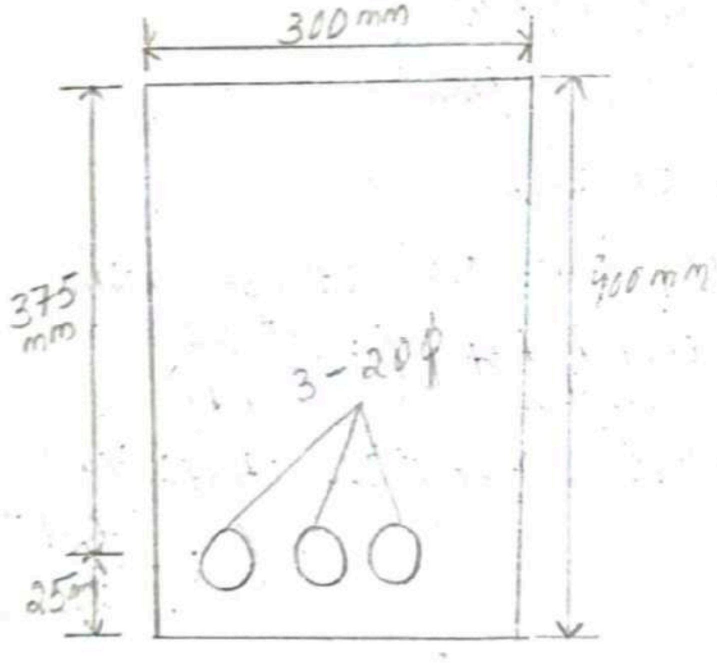
$A_{st}\ min \Rightarrow \frac{A_{st}}{bd} = \frac{0.85}{f_y} \Rightarrow \frac{A_{st}}{300 \times 375} = \frac{0.85}{550}$

$\Rightarrow A_{st} = 173\, mm^2$

$A_{st}\ max = 0.04 bD$

$= 0.04 \times 300 \times 400$

$= 4800\, mm^2$



Problem-2

A rectangular beam is 20cm wide and 40cm deep upto the centre of reinforcement. Find the reinforcement required if it has to resist a moment of 25 kNm.

(i) use M_{25} mix and SAIL-MA : 300HY grade steel

(ii) use M_{20} mix and Fe 415 grade steel

(i) Given data :-

$d = 40\,cm = 400\,mm$

$b = 20\,cm = 200\,mm$

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

$f_y = 300\ N/mm^2$

$BM = 25\ kNM$

Factored $BM = 1.5 \times 25 = 37.5\ kNm$

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

$$\Rightarrow 37.5 \times 10^6 = 0.87 \times 300 \times A_{st} \times 400 \left(1 - \frac{A_{st} \times 300}{200 \times 400 \times 25}\right)$$

$\Rightarrow A_{st} = 380\,mm^2$

Assume,

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

$\Rightarrow 380 = \frac{\pi}{4} \times (20)^2 \times x$

$\Rightarrow x = 2$ nos.

(ii)

e and 40cm
ment find
has to

0HY grade steel
ade steel

$\times 300$
$\times 400 \times 25$

A_{st} min

$\Rightarrow \frac{A_{st}}{bd} = \frac{0.85}{f_y}$

$\Rightarrow \frac{A_{st}}{200 \times 400} = \frac{0.85}{300}$

$\Rightarrow A_{st} = 226\ mm^2$ Assume, $e = 50mm$

$A_{st}\ max = 0.04bD = 0.04 \times 200 \times 450$
$= 3600mm^2$

(ii) $d = 40cm = 400mm$ $BM = 25\ kNm$
$b = 20cm = 200mm$
$f_{ck} = 20\ N/mm^2$
$f_y = 415\ N/m^2$
$BM = 25\ kNM$
Factored $BM = 1.5 \times 25 = 37.5\ kNm$

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

$\Rightarrow 37.5 \times 10^6 = 0.87 \times 415 \times A_{st} \times 400 \times \left(1 - \frac{A_{st} \times 415}{200 \times 400 \times 20}\right)$

$\Rightarrow A_{st} = \cancel{380}\ 280\ mm^2$

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

$\Rightarrow 280 = \frac{\pi}{4} \times (20)^2 \times x$

$\Rightarrow x = 2$ nos

Ast min

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

$\Rightarrow \frac{Ast}{200 \times 400} = \frac{0.85}{415}$

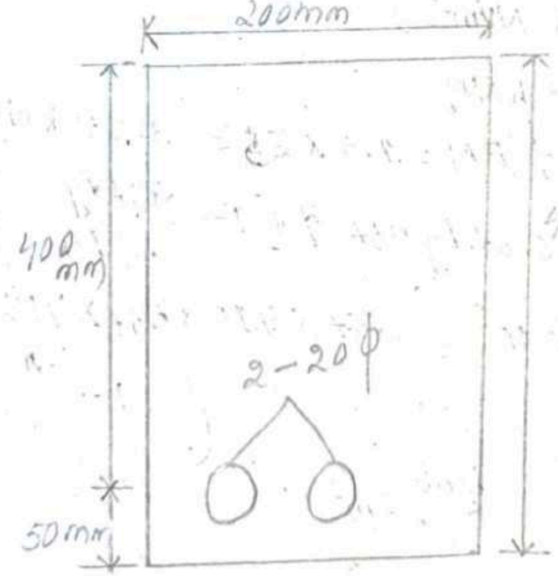
$\Rightarrow Ast = 163\ mm^2$

Ast max

$0.04bD$

$= 0.04 \times 200 \times 450$

$= 3600mm^2$



(28)

Problem-3

Design a
span which
15 kN/m a
M_{25} mix a

Given da

effective
Dead Lo
Live Loa

$\frac{L}{d} = 1$

Assume,

$\Rightarrow$

$\Rightarrow$

Assume

$e = 5$

$D = 4$

Self we

$= b\times$

$= 0.$

Problem-3

Design a rectangular beam for 4m effective span which is subjected to a Dead load of 15 kN/m and a Live load of 12 kN/m use M_{25} mix and Fe500 grade of steel.

Given data

effective span $(L) = 4m$

Dead Load (DL) $W_1 = 15\ kN/m$

Live Load (LL) $W_2 = 12\ kN/m$

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

$f_y = 500\ N/mm^2$

$\frac{L}{d} = 10$ to 20

Assume, $\frac{L}{d} = 10$

$\Rightarrow \frac{4 \times 10^3}{d} = 10$

$\Rightarrow d = 400mm$

$b = \frac{d}{1.5} = \frac{400}{1.5} = 266.66mm \simeq 3$

Assume

$e = 50mm$

$D = 400 + 50 = 450\ mm$

Self weight of the beam (W_3)

$= b \times D \times$ unit weight of concrete

$= 0.3 \times 0.4 \times 25 = 3.375\ kN/m$

$$w = w_1 + w_2 + w_3$$
$$= 15 + 12 + 3.375$$
$$= 30.375 \text{ kN/m}$$

$$BM = \frac{wl^2}{8}$$
$$= \frac{30.375 \times (4)^2}{8}$$
$$= 60.75 \text{ kNM}$$

Factored BM $= 60.75 \times 1.5$
$= 91.125 \text{ kNm}$

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

$$\Rightarrow 91.125 \times 10^6 = 0.87 \times 500 \times A_{st} \times 400 \times \left(1 - \frac{A_{st} \times 500}{300 \times 400 \times \ldots}\right)$$

$$\Rightarrow A_{st} = 587 \text{ mm}^2$$

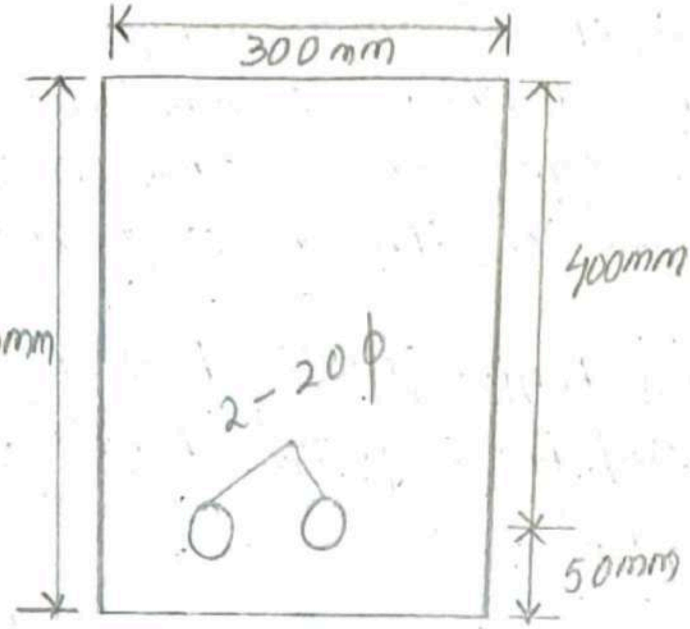
$$A_{st} = \frac{\pi}{4}(20)^2\, x$$
$$\Rightarrow 587 = \frac{\pi}{4} \times (20)^2 \times x$$
$$\Rightarrow x = 2 \text{ nos}$$

A_{st} required $= \frac{\pi}{4} \times (20)^2 \times 2$
$= 629 \text{ mm}^2$

A_{st} min $\Rightarrow \frac{A_{st}}{bd} = \frac{0.85}{f_y}$

$$\Rightarrow \frac{A_{st}}{300 \times 400} = \frac{0.85}{500}$$
$$\Rightarrow A_{st} = 204 \text{ mm}^2$$

$A_{st}\, max = 0.04bD = 0.04 \times 300 \times 450 = 7200 mm^2$



Doubly reinforced beam :-

$C_1 = 0.36 f_{ck}\, x_u b - 0.45 f_{ck} A_{sc}$

$C_2 = f_{sc} \times A_{sc}$

$C = 0.36 f_{ck}\, x_u b - 0.45 f_{ck} A_{sc} + f_{sc} \times A_{sc}$

$$\boxed{C = 0.36 f_{ck}\, x_u b + A_{sc} (f_{sc} - 0.45 f_{ck})}$$

$$\frac{0.0035}{x_u} = \frac{\varepsilon_{sc}}{x_u - d'}$$

$\Rightarrow \varepsilon_{sc} = 0.0035 \left(1 - \frac{d'}{x_u}\right)$

$MR = C \times z$

$MR = C \times (d - d')$

$T = 0.87 f_y A_{st_1} \times 0.87 f_y A_{st_2} (d - d')$

$T = 0.87 f_y A_{st} (d - d')$

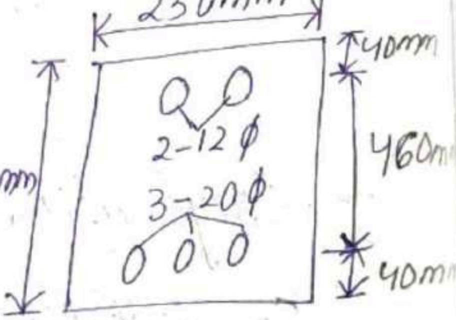
Problem-1

Find the MR of a beam 25cm by 50cm deep if it is reinforced with 2-12 mm bar in compression zone and 3-20 mm in tension zone each at an effective cover of 40mm.

Assume,

(i) M_{20} Mix and Fe415 grade of steel

(ii) M_{25} mix and Fe500 grade of steel.



Given data

(i) $b = 25cm = 250mm$

$D = 50cm = 500mm$

$d' = 40mm$

$A_{st} = \frac{\pi}{4} \times 20^2 \times 3 = 942.47\ mm^2$

$A_{sc} = \frac{\pi}{4} \times 12^2 \times 2 = 226.19mm^2$

$x_u = 0.48d = 0.48 \times 460 = 220.8\ mm$

$$\varepsilon_{sc} = 0.0035\left(1 - \frac{d'}{x_u}\right)$$

$$= 0.0035\left(1 - \frac{40}{220.8}\right)$$

$$= 0.002$$

$$f_{sc} = 0.975 f_y$$

$$= 0.975 \times 415$$

$$= 404.625\ N/mm^2$$

$C = 0.36\, f_{ck}\, x_u b - 0.45\, f_{ck} A_{sc} + f_{sc} A_{sc}$

$= 0.36 \times 20 \times 220.8 \times 250 - 0.45 \times 20 \times 226.19$
$+ 404.625 \times 226.19$

$= 486926.41\,N$

$T = 0.87\, f_y A_{st}$
$= 0.87 \times 415 \times 942.47$
$= 340278.79\,N$

Re-designed.

$x_u = 150mm$

$C = 0.36\, f_{ck}\, x_u b + A_{sc}(f_{sc} - 0.45 f_{ck})$

$= 0.36 \times 20 \times 150 \times 250 + 226.19 (404.625 - 0.45 \times 20)$

$= 359486.41\,N$

$T = 0.87\, f_y A_{st}$

$= 0.87 \times 415 \times 942.47$

$= 340278.79\,N$

$C = T$

$MR = C \times Z$

$= C \times (d - d')$

$= 359486.41 \times (460 - 40)$

$= 359486.41 \times 420 = 20452492.2\,Nmm$

$= 20.45\,kNM$

ii)

$b = 25\,cm = 250\,mm$

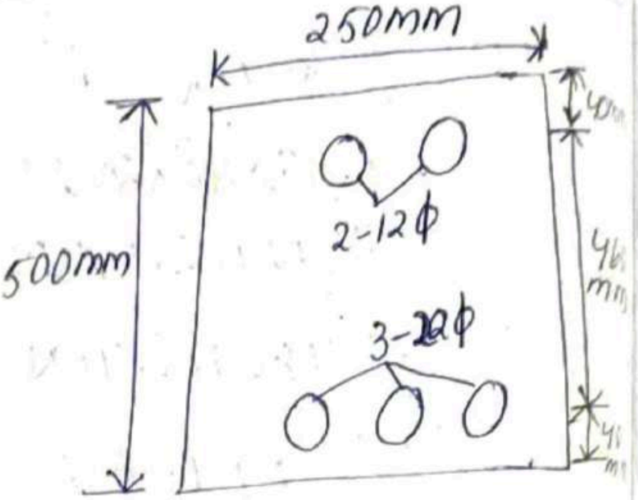
$D = 50\,cm = 500\,mm$

$d' = 40\,mm$

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

$f_y = 500\,N/mm^2$

$d = 500 - 40 = 460$



$x_u = 0.46\,d$

$= 0.46 \times 460$

$= 211.6\,mm$

$$\varepsilon_{sc} = 0.0035\left(1 - \frac{d'}{x_u}\right)$$

$$= 0.0035\left(1 - \frac{40}{221.6}\right)$$

$= 0.002$

$f_{sc} = 0.975 f_y$

$= 0.975 \times 500$

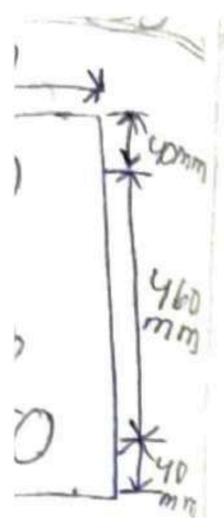
$= 487.5\,N/mm^2$

$$A_{st} = \frac{\pi}{4} \times 3 \times 20^2$$

$= 942.47\,mm^2$

$$A_{sc} = \frac{\pi}{4} \times 12^2 \times 2$$

$= 226.19\,mm^2$



$C = 0.36 f_{ck} x_u b + A_{sc}(f_{sc} - 0.45 f_{ck})$

$= 0.36 \times 25 \times 211.6 \times 250 + 226.19(487.5 - 0.45 \times 25)$

$= 583822.98 \, N$

$T = 0.87 f_y A_{st}$

$= 0.87 \times 500 \times 942.47$

$= 409974.45 \, N$

Re-designed

$x_u = 150mm$

$C = 0.36 f_{ck} x_u b + A_{sc}(f_{sc} - 0.45 f_{ck})$

$= 0.36 \times 25 \times 150 \times 250 + 226.19(487.5 - 0.45 \times 25)$

$= 445222.98 \, N$

$T = 0.87 f_y A_{st}$

$= 0.87 \times 500 \times 942.47$

$= 409974.45 \, N$

$C = T$

$M_R = C \times z = C \times (d - d')$

$= 445222.98 \times (460 - 40)$

$= 186993651.6 \, Nmm$

$= 186.99 \, kNM$

Design a rectangular beam for an effective span of 6m the super imposed load is 60 kN/m and size of Beam is limited to 30X60cm overall use M_{20} mix and Fe415 grade of steel.

Given data

$D = 600mm$

$b = 300mm$

$l = 6m = 60mm$

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

$f_y = 415 N/mm^2$

$w_1 = 60 kNm$

Assume,

$e = 50mm$

$d = 550 mm$

self. weight of the beam

$= b \times D \times$ unit weight of concrete

$= 0.3 \times 0.6 \times 25$

$= 4.5 kN/m$

$w = w_1 + w_2$

$= 60 + 4.5$

$= 64.5 kN/m$

$BM = \frac{wl^2}{8} = \frac{64.5 \times (6)^2}{8}$

$= 290.25 kNm$

eve

grade

Factored BM $= 290.25 \times 1.5$

$= 435.375$ kNm

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

$= 0.138 \times 20 \times 300 \times (550)^2$

$= 250.47$ kNm

$0.87 f_y \times A_{st_1} = 0.36 f_{ck} x_u b$

$\Rightarrow 0.87 \times 415 \times A_{st_1} = 0.36 \times 20 \times 0.48 \times 550 \times 300$

$\Rightarrow A_{st_1} = 1579.39 \text{ mm}^2$

$M_u - M_{lim} = A_{sc} (f_{sc} - 0.45 f_{ck}) \times (d - d')$

$\Rightarrow (435.375 - 250.47) \times 10^6 = A_{sc} (404.625 - 0.45 \times 20) \times (550 - 50)$

$\Rightarrow A_{sc} = 934.74 \text{ mm}^2$

$\varepsilon_{sc} = 0.0035 \left(1 - \frac{d'}{x_u}\right)$

$= 0.0035 \left(1 - \frac{50}{0.48 \times 550}\right)$

$= 0.002$

$f_{sc} = 0.975 f_y$

$= 0.975 \times 415$

$= 404.625 \text{ N/mm}^2$

$0.87 f_y A_{st2} = f_{sc} \times A_{sc}$

$\Rightarrow 0.87 \times 415 \times A_{st2} = 404.625 \times 934.74$

$\Rightarrow A_{st2} = 1047.55 \text{ mm}^2$

$A_{st} = A_{st1} + A_{st2}$

$= 1579.39 + 1047.55$

$= 2626.94\ mm^2$

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

$\Rightarrow 2626.94 = \frac{\pi}{4} \times (20)^2 \times x$

$\Rightarrow x = 9$ nos.

A_{st} required $= \frac{\pi}{4} \times (20)^2 \times 9$

$A_{st} = 2827.43\ mm^2$

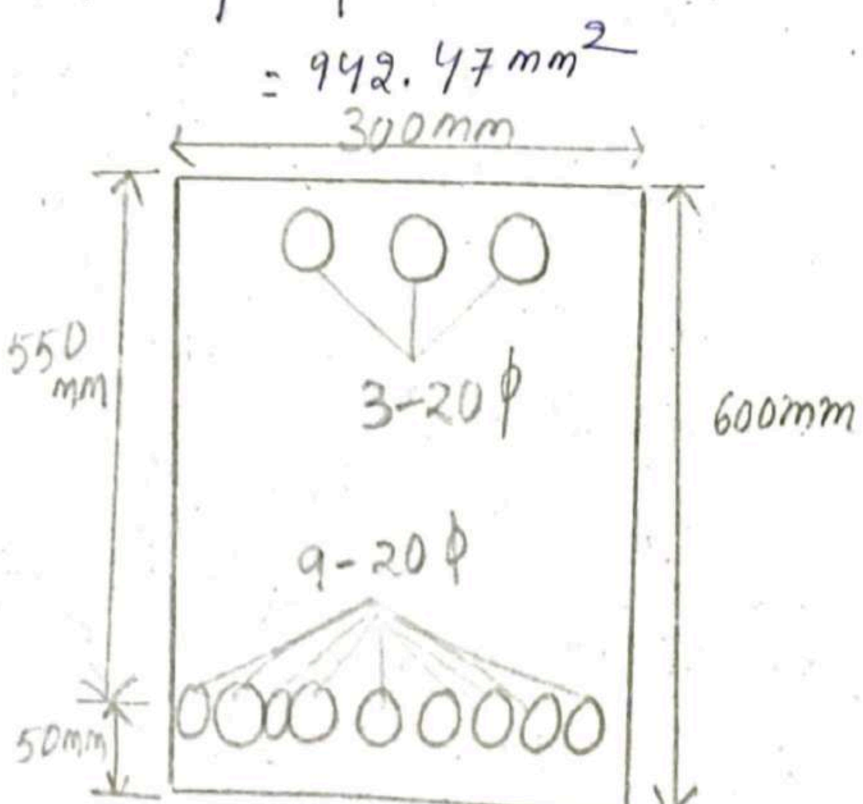
$A_{sc} = \frac{\pi}{4} \times (20)^2 \times x$

$\Rightarrow 934.74 = \frac{\pi}{4} \times (20)^2 \times x$

$\Rightarrow x = 3$ nos

A_{sc} required $= \frac{\pi}{4} \times (20)^2 \times 3$

$= 942.47\ mm^2$

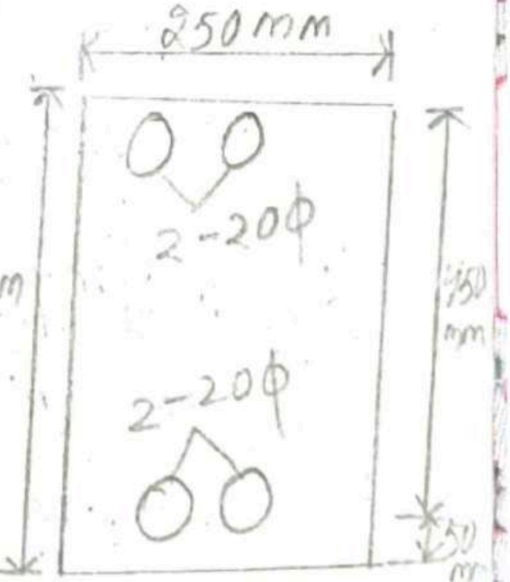


Grade of concrete	Grade of steel			
	Fe250	Fe415	Fe500	Fe550
	0.148 $f_{ck} bd^2$	0.138 $f_{ck} bd^2$	0.133 $f_{ck} bd^2$	0.130 $f_{ck} bd^2$
M_{20}	$2.9 bd^2$	$2.76 bd^2$	$2.26 bd^2$	$2.60 bd^2$
M_{25}	$3.70 bd^2$	$3.45 bd^2$	$3.33 bd^2$	$3.25 bd^2$
M_{30}	$4.44 bd^2$	$4.14 bd^2$	$3.99 bd^2$	$3.90 bd^2$

Problem -

Find the MR of a beam section 25cm by 50cm deep if it is reinforced with 2-20mm bar in compression and Tension is at an effective cover of 50mm. use M_{20} Mix and fe415 grade of steel.

Given data



$b = 250mm$

$D = 500mm$

$d = 500 - 50 = 450\ mm$

$e = 50\ mm$

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

$f_y = 415\ N/mm^2$

$A_{st} = \frac{\pi}{4} \times (20)^2 \times 2 = 628.31\ mm^2$

$A_{sc} = \frac{\pi}{4} \times (20)^2 \times 2 = 628.31 mm^2$

$x_u = 0.48d = 0.48 \times 450 = 216$ mm

$\varepsilon_{sc} = 0.0035\left(1 - \frac{d'}{x_u}\right)$

$= 0.0035\left(1 - \frac{50}{216}\right)$

$= 0.002$

$f_{sc} = 0.975 f_y$

$= 0.975 \times 415$

$= 404.625 \ N/mm^2$

$C = 0.36 f_{ck} x_u b + \cancel{0.45} A_{sc}(f_{sc} - 0.45 f_{ck})$

$= 0.36 \times 20 \times 216 \times 250 + 628.31(404.625 - 0.45\times$

$= 637375.1438$ N

$T = 0.87 f_y A_{st}$

$= 0.87 \times 415 \times 628.31$

$= 226851.3255$ N

Re-designed

$x_u = 150$ mm

$C = 0.36 \times 20 \times 150 \times 250 + 628.31(404.625 - 0.45$

$= 518575.14$ N

$T = 0.87 f_y A_{st}$

$= 0.87 \times 415 \times 628.31$

$= 226851.3255$ N

Re-designed

$x_u = 25 mm$

$C = 0.36 \times 20 \times 25 \times 250 + 628.31(404.625 - 0.45 \times 20)$

$= 293575.1431 N$

$T = 0.87 f_y A_{st}$

$= 0.87 \times 415 \times 628.31$

$= 226851.3255 N$

$C = T$ (ok)

$MR = C \times z$

$= C \times (d - d')$

$= 293575.1431 \times (450 - 50)$

$= 117414857.2 Nmm$

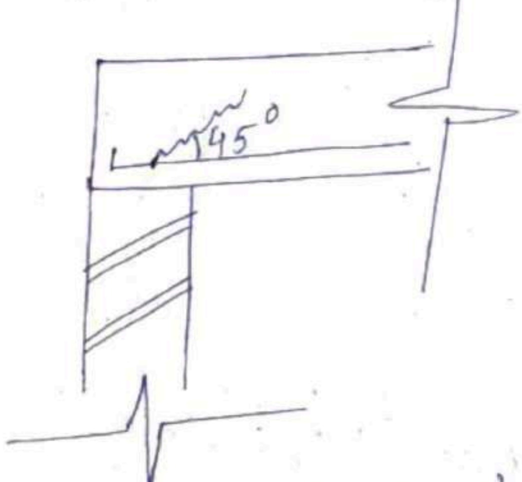
$= 117.4 kNm$

SHEAR

i) Rate of change of BM is known as shear force.

Experimental studies conform the followin 3 different modes of failure due to possibl combination of shear force and BM at a given section.

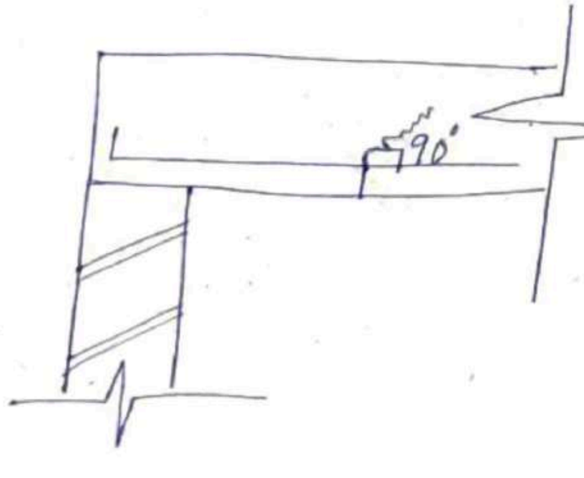
1- Diagonal Tension failure :-



i) It occurs in large shear force and less B

i) Web shear cause cracks which Progress with 45° with horizontal.

2. Flexural shear failure :-

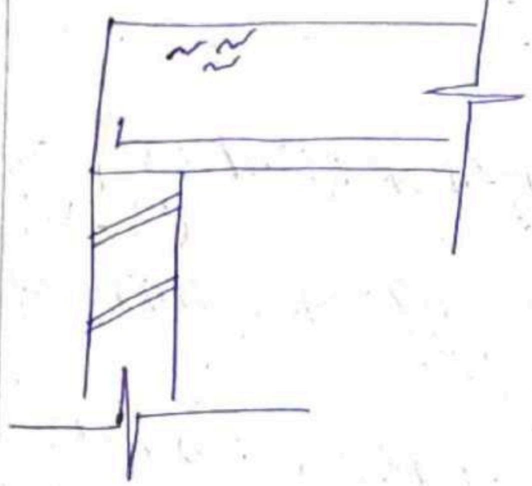


(i) Large BM less shear force.

(ii) Such cracks are normally at 90°.

(iii) Steel its in Flexural tension shear.

(3) Diagonal compression Failure:-

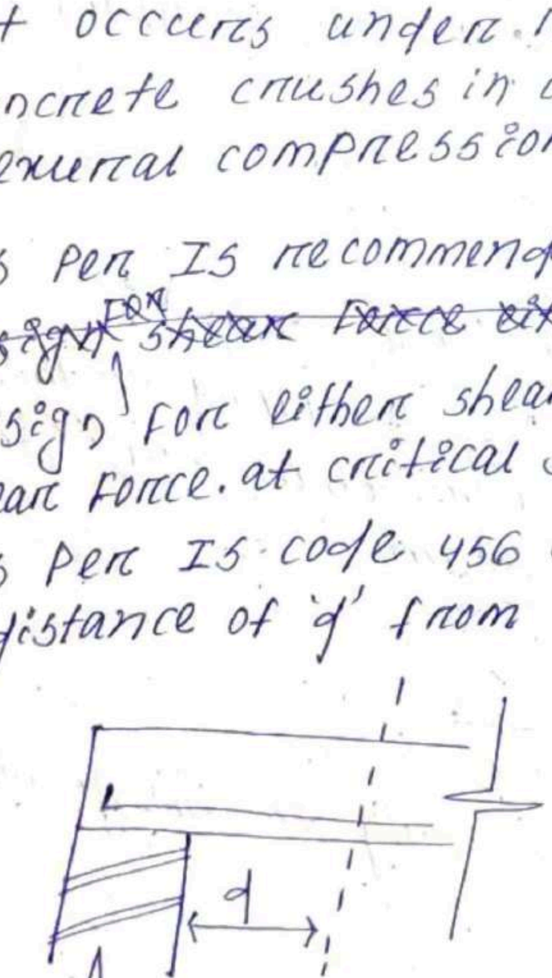


(i) It occurs under large shear force.

(ii) concrete crushes in compression due to flexural compression.

(iii) As per IS recommendation the beam can be ~~design for shear force either~~ design for either shear force or maximum shear force at critical section.

(iv) As per IS code 456 critical section is at a distance of 'd' from the face of support.



Nominal shear stress :- (τ_v)

(i) It is the average shear stress developed in a cross section (c/s).

(ii) It is generally denoted by

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

Design shear strength of Reinforced concrete (τ_c) :-

(i) τ_c is the shear strength of Reinforced concrete.

(ii) It depends upon the grade of concrete and percentage of main tension Reinforcement.

$$\boxed{\tau_c = \frac{V_c}{bd}}$$

Max^m shear stress (τ_{cmax}) :-

(i) The shear stress developed in the beam should not be more than Max^m shear stress of the beam.

$$\boxed{\tau_v \ngtr \tau_{cmax}}$$

(ii) τ_{cmax} depends only on the grade of concrete.

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Stress in shear reinforcement:-
Nominal shear force, $V_u = \tau_v bd$
Design shear force, $V_c = \tau_c bd$
extra shear force, $V_s = V_u - V_c$
$\Rightarrow V_s = (\tau_v - \tau_c) bd$

~~Maximum shear reinforcement~~
Design step:-

Step-1
Find max^m shear force

Step-2
calculate Nominal shear stress and compare with τ_c max

Step-3
calculate shear strength of concrete (τ_c)

Step-4
calculate Net shear force

Step-5
Design of shear reinforcement

Step-6
calculate Maximum spacing

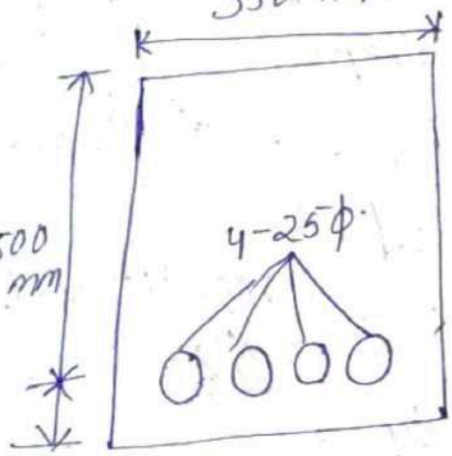
A RC beam has an effective depth of 500mm and a breath of 350mm it contain 4-25 mm bars if

i) $F_{ck} = 20\ N/mm^2$, $f_y = 250\ N/mm^2$

ii) $F_{ck} = 25\ N/mm^2$, $f_y = 415\ N/mm^2$

calculate the shear reinforcement needed for a factored shear force of 350 KN.

Given data



i) $b = 350\,mm$

$d = 500\,mm$

$a = 50\,mm$

$D = 550\,mm$

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

$f_y = 250\ N/mm^2$

$SF = 350\ KN$

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

$= 1963.49\ mm^2$

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

$= \frac{350 \times 10^3}{350 \times 500}$

$= 2\ N/mm^2$

$\tau_c max =$

$P_t = 1$

$= 1$

$=$

$x = 1.1$

$x_1 = 1$

$x_2 = 1$

$y = y_1$

$y = 0.$

$y =$

τ_c

$\tau_c <$

permic

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00mm
5 mm

for

$\tau_c\,max = 2.8\ N/mm^2$

$$P_t = 100\,\frac{A_{st}}{bd}$$

$$= 100 \times \frac{1963.49}{500 \times 350}$$

$$= 1.12\%$$

$x = 1.12 \quad y = ?$

$x_1 = 1 \quad y_1 = 0.62$

$x_2 = 1.25 \quad y_2 = 0.67$

$$y = y_1 + \frac{(y_2 - y_1)}{(x_2 - x_1)} \times (x - x_1)$$

$$y = 0.62 + \frac{(0.67 - 0.62)}{(1.25 - 1)} \times (1.12 - 1)$$

$y = 0.64$

$\tau_c = 0.64$

$\tau_c < \tau_v$ (OK)

permiciable force $\tau_c \times bd$

$= 0.64 \times 350 \times 500$

$= 112000\ N$

strength of shear reinforcement

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

$= 350 \times 10^3 - 112000$

$= 238000\ N$

(ii)

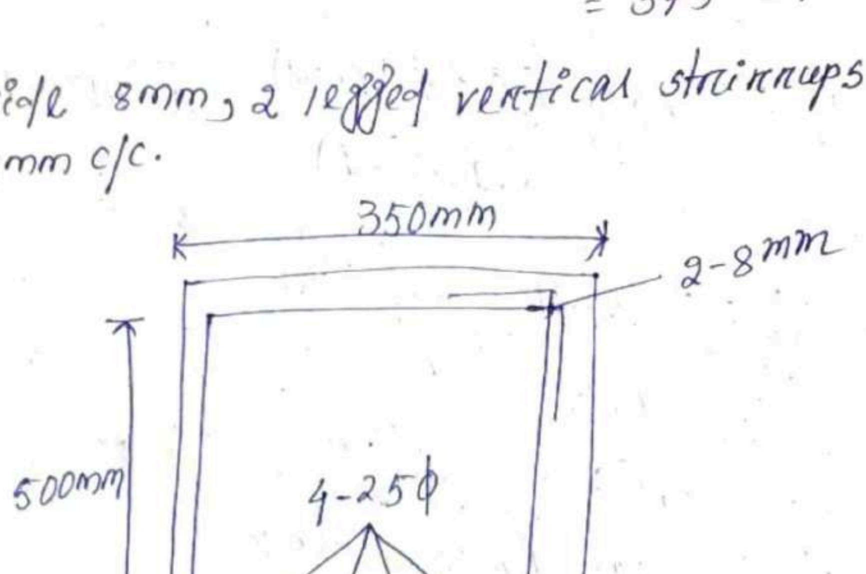
Assume bar diameter of stirrups = 8mm and 2-legged stirrups.

$$A_{sv} = 2 \times \frac{\pi}{4} \times 8^2$$
$$= 100.53 mm^2$$

$$S_v = \frac{0.87 f_y A_{sv} d}{V_{us}}$$
$$= \frac{0.87 \times 250 \times 100.53 \times 500}{238000}$$
$$= 45.93 mm \cong 50 mm$$

check max^m spacing = $0.75d = 0.75 \times 500$
$= 375$ mm

Provide 8mm, 2 legged vertical strirrups @50mm c/c.



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

$= 1963.49 \ mm^2$

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

$= \frac{350 \times 10^3}{350 \times 500}$

$= 2 \ N/mm^2$

$\tau_{c\,max} = 2.8 \ N/mm^2$

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

$= 100 \times \frac{1963.49}{350 \times 500}$

$= 1.12\%$

$x = 1.12 \quad y = ?$

$x_1 = 1 \quad y_1 = 0.62$

$x_2 = 1.25 \quad y_2 = 0.67$

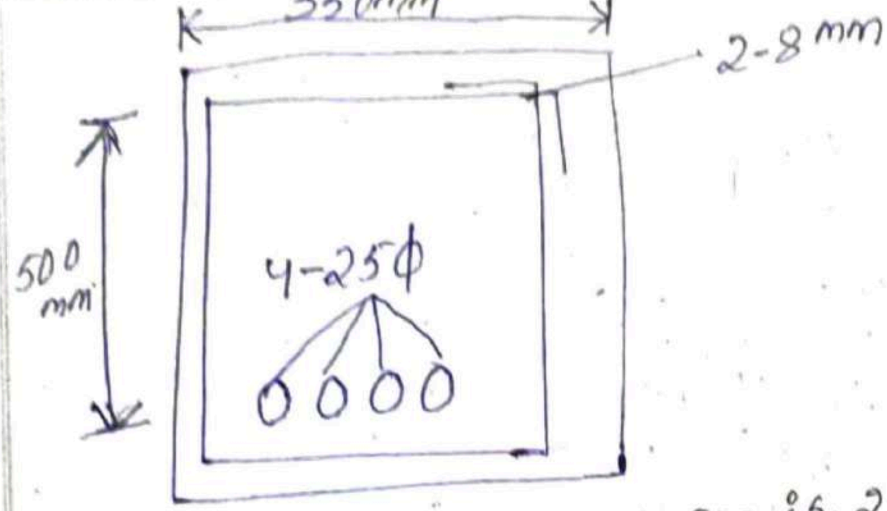
$y = y_1 + \frac{(y_2 - y_1)}{(x_2 - x_1)} \times (x - x_1)$

$y = 0.62 + \frac{(0.67 - 0.62)}{(1.25 - 1)} \times (1.12 - 1)$

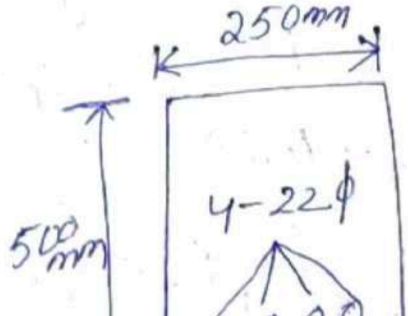
$y = 0.64$

$\tau_c = 0.64$

$\tau_c < \tau_v$ (ok)



2- An RC beam of span 5m is 250 mm wide and 500mm deep to the centre of tensile reinforcement which consist of 4 bars of 22mm diameter. the beam carries a udl of 30 kN/m included of its weight. design the shear reinforcement. use M_{20} and Fe415 grade of steel.



Given data :-

$l = 5m$

$b = 250mm$

$d = 500mm$

$w = 30 \ kN/m$

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

$f_y = 415 \ N/mm^2$

shear force $= \frac{wl}{2} = \frac{30 \times 5}{2} = 75 \ kN$

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

$= 1520.53 \ mm^2$

Factored $V_u = 1.5 \times 75$

$= 112.5 \ kN$

Permissiable force $= \tau_c \times bd$.

$= 0.64 \times 350 \times 500$

$= 112000\ N$

Strength of shear reinforcement

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

$= 350 \times 10^3 - 112000$

$= 238000\ N$

Assume bar diameter of stirrups = 8mm and 2-legged stirrups.

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

$= 100.53\ mm^2$

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

$= \frac{0.87 \times 415 \times 100.53 \times 500}{238000}$

$= 76.25\ mm \cong 80\ mm$

check max^m spacing $= 0.75d$

$= 0.75 \times 500$

$= 375\ mm$

Provide 8mm, 2 legged vertical strirrups @ 80mm c/c

2-

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

$= \frac{112.5 \times 10^3}{250 \times 500}$

$= 0.9 \, N/mm^2$

$\tau_c max = 2.8 \, N/mm^2$

$Pt = 100 \frac{Ast}{bd}$

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

$= 1.21 \%$

$x = 1.12 \quad y = ?$

$x_1 = 1 \quad y_1 = 0.62$

$x_2 = 1.25 \quad y_2 = 0.67$

$y = y_1 + \frac{(y_2 - y_1)}{(x_2 - x_1)} (x - x_1)$

$y = 0.62 + \frac{(0.67 - 0.62)}{(1.25 - 1)} (1.12 - 1)$

$y = 0.64$

$\tau_c = 0.64$

$\tau_c < \tau_v$ (ok)

Permiciable force $= \tau_c \times bd$

$= 0.64 \times 250 \times 500$

$= 80000 N$

$V_{us} = V_u - \tau_c b d$

$= 112.5 \times 10^3 - 80000$

$= 32500 N$

Assume bar diameter of stirrups = 8mm and 2-legged stirrups.

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

$= 100.53 mm^2$

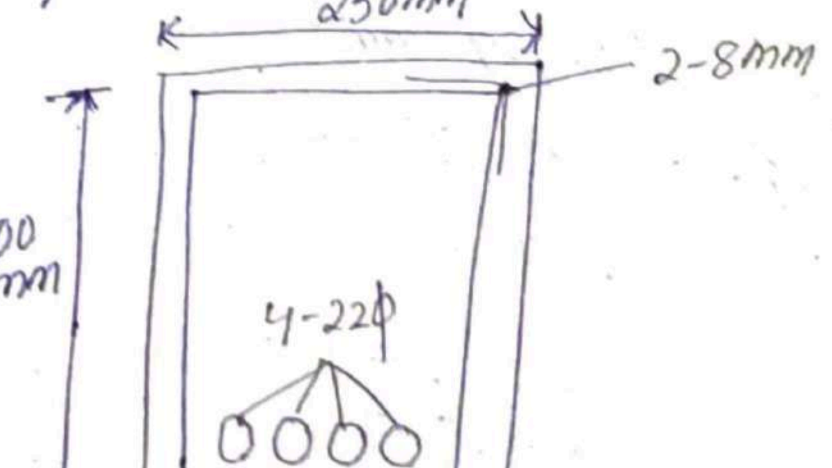
$$S_v = \frac{0.87 f_y A_{sv} d}{V_{us}}$$

$$= \frac{0.87 \times 415 \times 100.53 \times 500}{32500}$$

$= 558.4 mm \cong 600mm$

check max^n spacing $= 0.75d = 0.75 \times 500$
$= 375 mm$

Provide 8mm, 2-legged vertical stirrups @ 300 mm c/c.



An RC beam of span 6.5 m is 300mm wide and 750mm deep to the centre of tensile reinforcement which consist of 6 bars of 20mm diameter the beam carries a load of 45 kN/m including it weight design the shear reinforcement of 50% of the tensile reinforcement is curtailed near the support use M_{20} and Fe415 grade of steel.

Given data

$L = 6.5m$
$b = 300mm$
$d = 750mm$
$w = 45\ kN/m$
$f_{ck} = 20\ N/mm^2$
$f_y = 415\ N/mm^2$

$$\text{Shear force} = \frac{wL}{2}$$
$$= \frac{45 \times 6.5}{2}$$
$$= 146.25\ kN$$

$$A_{st} = \frac{\pi}{4} \times (20)^2 \times 6$$
$$= 1884.95\ mm^2$$

$$50\% = 942.475\ mm^2$$

$$\tau_v = \frac{V_u}{bd}$$
$$= \frac{146.25 \times 10^3}{300 \times 750}$$
$$= 0.65\ N/mm^2$$

$$\tau_{c\,max} = 2.8\ N/mm^2$$

$$Pt = 100 \frac{Ast}{bd}$$

$$= 100 \times \frac{942.475}{300 \times 750}$$

$$= 0.41$$

$x = 0.41$ $\quad y = ?$

$x_1 = 0.25$ $\quad y_1 = 0.36$

$x_2 = 0.50$ $\quad y_2 = 0.48$

$$y = y_1 + \frac{(y_2 - y_1)}{(x_2 - x_1)} \times (x - x_1)$$

$$= 0.36 + \frac{(0.48 - 0.36)}{(0.50 - 0.25)} \times (0.41 - 0.25)$$

$$= 0.02$$

$\tau_c = 0.02$

$\tau_c < \tau_v$

Permiciable force $= \tau_c \times bd$

$= 0.02 \times 300 \times 750$

$= 4500N$

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

$= 146.25 \times 10^3 - 4500$

$= 141750\ N$

Assume bar diameter of stirrups = 8mm and 2-legged stirrups.

$A_{sv} = 2 \times \frac{\pi}{4} \times 8^2 = 100.53 mm^2$

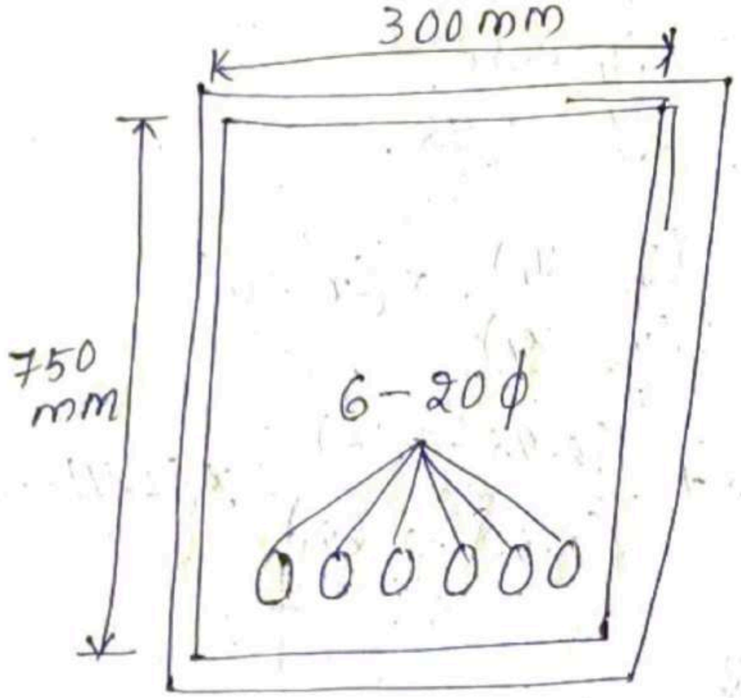
$$S_v = \frac{0.87 f_y A_{sv} d}{V_{us}} = \frac{0.87 \times 415 \times 100.53 \times 750}{141750} = 192.04\ mm \simeq 200\ mm$$

check Max^n spacing $= 0.75 d$

$= 0.75 \times 750$

$= 562.5$ mm

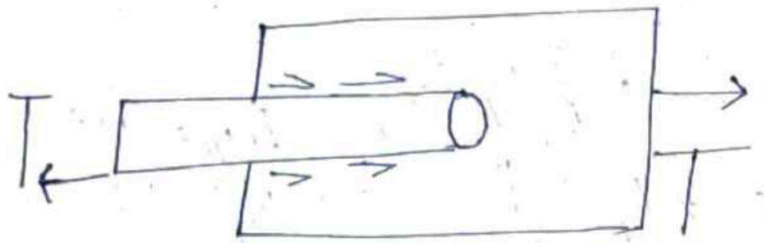
Provide 8mm, 2 legged vertical stirrups @200mm c/c.



Bond and development length :-

PS

(i) Bond stress is define as the shear force per unit of Nominal surface area of a reinforcement bar acting parallel to the bar on the interface bet^n the bar and surrounding concrete.

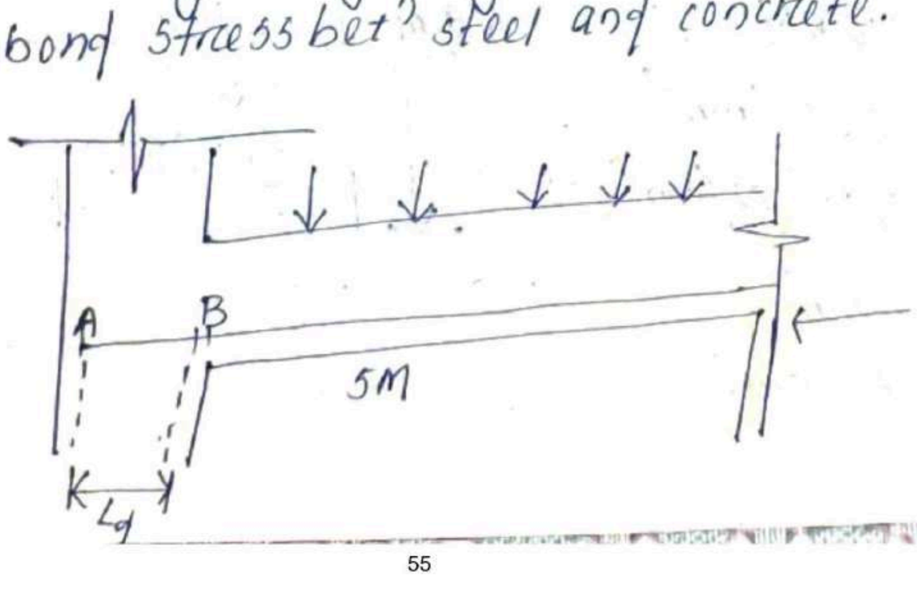


(ii) Basic requirement in the reinforced concrete structure is that steel and surrounding concrete act together and there should be no slip of the bar relative to its surrounding concrete.

(iii) slippage of bar may result in overall failure of the beam.

(iv) A beam may continue to carry load as long as the bars are anchored at the end.

(v) Due to unbalanced tension force shear stress is acting along longitudinal direction, i.e. called bond stress bet^n steel and concrete.



$$\text{stress} = \frac{w}{A}$$

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

$$\boxed{T = \frac{\pi}{4} \times \phi^2 \times \frac{f_y}{1.15}} \quad \text{——— ①}$$

$$T = \pi \phi L_d \times \tau_{bd}$$

$$\frac{\pi}{4} \times \phi^2 \times \frac{f_y}{1.15} = \pi \phi L_d . \tau_{bd}$$

$$\boxed{\Rightarrow L_d = \frac{0.87 f_y}{4 \tau_{bd}}}$$

Fe415, Fe500 →

$45^\circ = 4\phi$

$90^\circ = 8\phi$

$180^\circ = 16\phi$

1. A simply supported beam is 25 cm by 50 cm has 2-20mm tor bars going into the support into the shear force at the centre of support is 110 kN at working loads. determine the encourage length. Assume M_{20} Mix and Fe415 grade of steel.

Given data:-

$b = 25 cm$

$D = 50 cm$

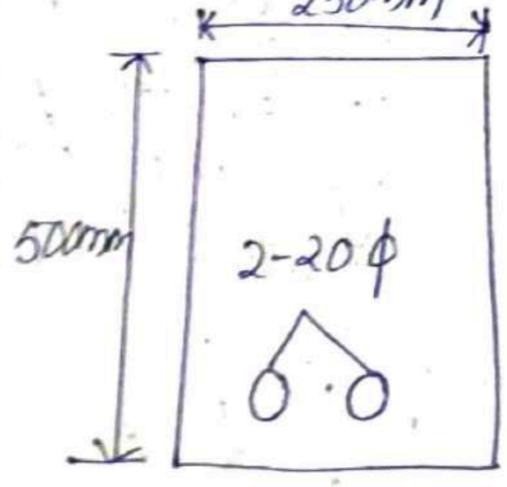
$SF = 110 kN$

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

$f_y = 415 N/mm^2$

$e = 50 mm$

$d = 450 mm$



Factor SF = SF × FOS

= 110 × 1.5

= 165 kN

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

$= 628.31 mm^2$

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

$\Rightarrow M_u = 0.87 \times 415 \times 628.31 \times 450 \times \left(1 - \frac{628.31 \times 415}{250 \times 450 \times 20}\right)$

$\Rightarrow M_u = 90253049.39 \text{ N·mm}$

$= 90.25 \text{ kNm}$

$\tau_{bd} = 1.2 \text{ N/mm}^2$

$L_d = \frac{0.87 \times 415 \times \phi}{4 \times 1.2 \times 1.6}$

$\Rightarrow L_d = 47\phi$

Assume, 90° of anchorage :

for $L_0 = 8 \times \phi$

$= 8 \times 20 = 160 mm$

$L_d \leq \frac{M_1}{V} + L_0$

$\Rightarrow 47\phi = 1.3 \times \frac{90.25 \times 10^6}{165 \times 10^3} + 160$

$\Rightarrow \phi =$ ~~16 mm~~ 21 mm

FLANGED BEAM (clause no - 23.1)

Effective width of flanges :- (page no. 37)

(a) For T-beam :-

$$\boxed{b_f = \frac{l_0}{6} + b_w + 6D_f}$$

(b) For L-beam :-

$$\boxed{b_f = \frac{l_0}{12} + b_w + 3D_f}$$

(c) For Isolated T-beam :-

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

(d) For isolated L-beam :-

$$\boxed{b_f = \frac{0.5\, l_0}{\left(\frac{l_0}{b}\right) + 4} + b_w}$$

where,

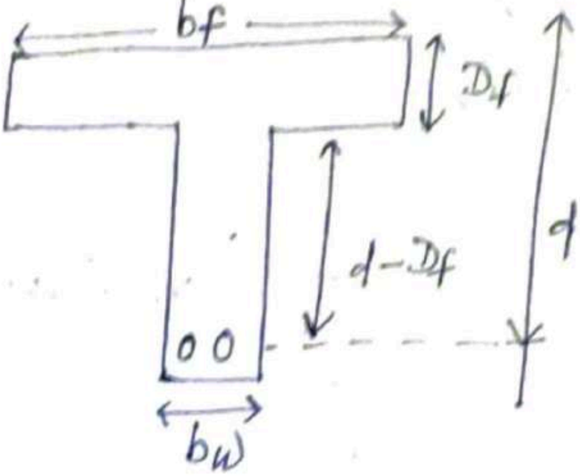
b_f = effective width of flange.

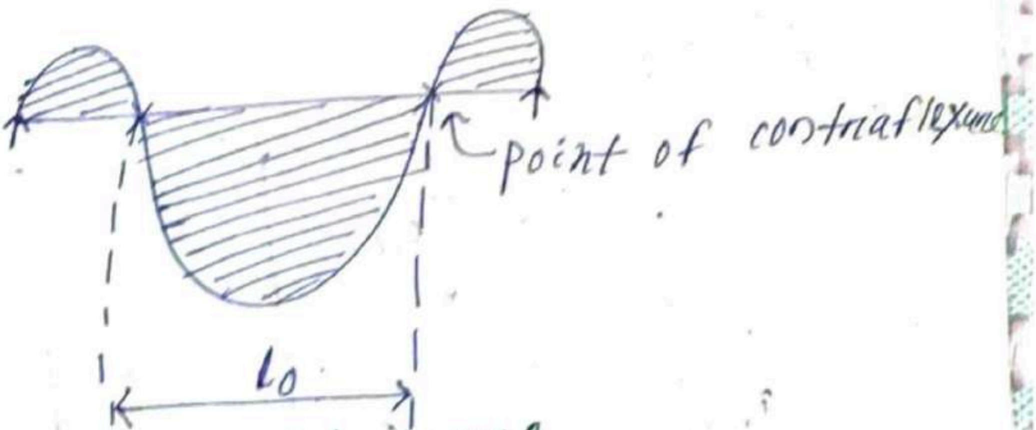
l_0 = distance between points of zero mom in the beam

b_w = breath of the web

D_f = thickness of flange

b = actual width of the flange





Analysis of flanged beam:-

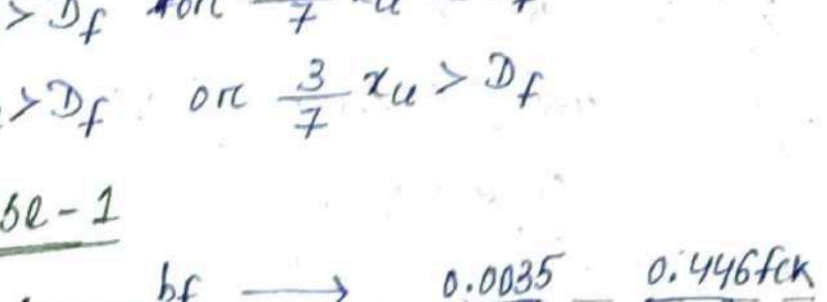
case:-

(1) $x_u < D_f$

(2) $x_u > D_f$ for $\frac{3}{7} x_u < D_f$

(3) $x_u > D_f$ or $\frac{3}{7} x_u > D_f$

case-1



$C = 0.36 f_{ck} b_f x_u$

$T = 0.87 f_y A_{st}$

$C = T$

$$\Rightarrow \boxed{x_u = \frac{0.87 f_y A_{st}}{0.36 f_{ck} b_f}}$$

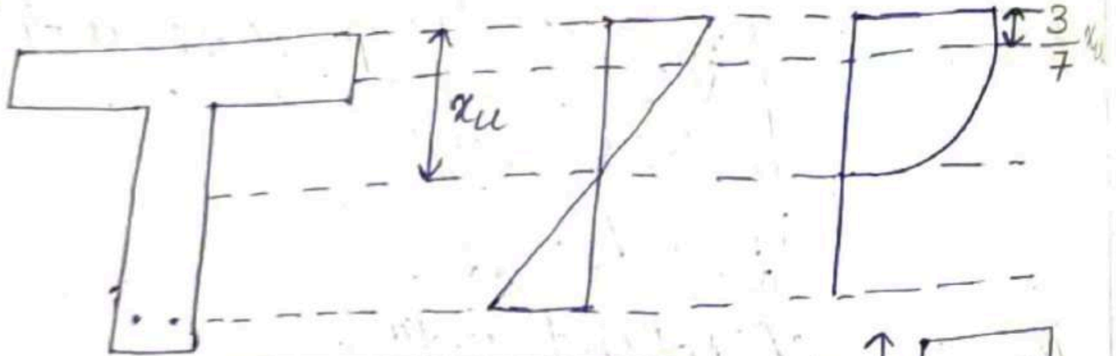
$x_u < D_f$

sign similar to rectangular beam.

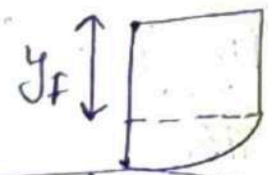
case-2 :-

$x_u > D_f$

$\frac{3}{7} x_u < D_f$:-



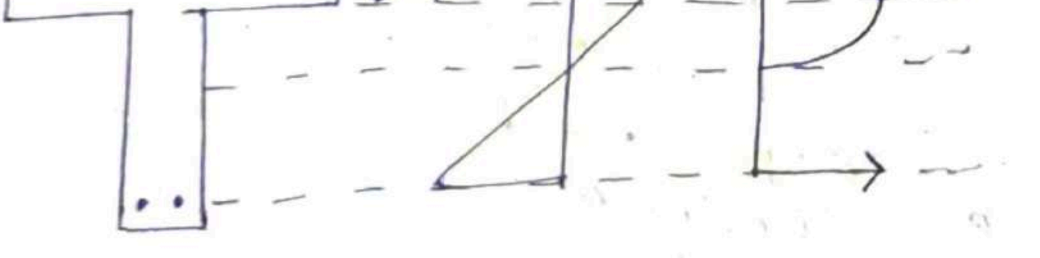
$$\boxed{y_f = 0.15 x_u + 0.65 D_f}$$



$$\boxed{MOR = 0.36 f_{ck} b_w x_u (d - 0.42 x_u) + 0.446 f_{ck} (b_f - b_w) y_f (d - y_f/2)}$$

$$\boxed{x_u = \frac{0.87 f_y A_{st} - 0.446 f_{ck} (b_f - b_w) y_f}{0.36 f_{ck} b_w}}$$

case-3 :- $x_u > D_f$



if,

$\frac{3}{7} x_u > D_f$

* first calculate, x_u, then $\frac{3}{7} x_u$.
then compare it with D_f

$$C = C_w + C_f$$

$$C_w = 0.36 f_{ck} x_u b_w$$

$$C_f = 0.446 f_{ck} (b_f - b_w) \times D_f$$

$$C = 0.36 f_{ck} b_w x_u + 0.446 f_{ck} (b_f - b_w) \times D_f$$

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

$C = T$

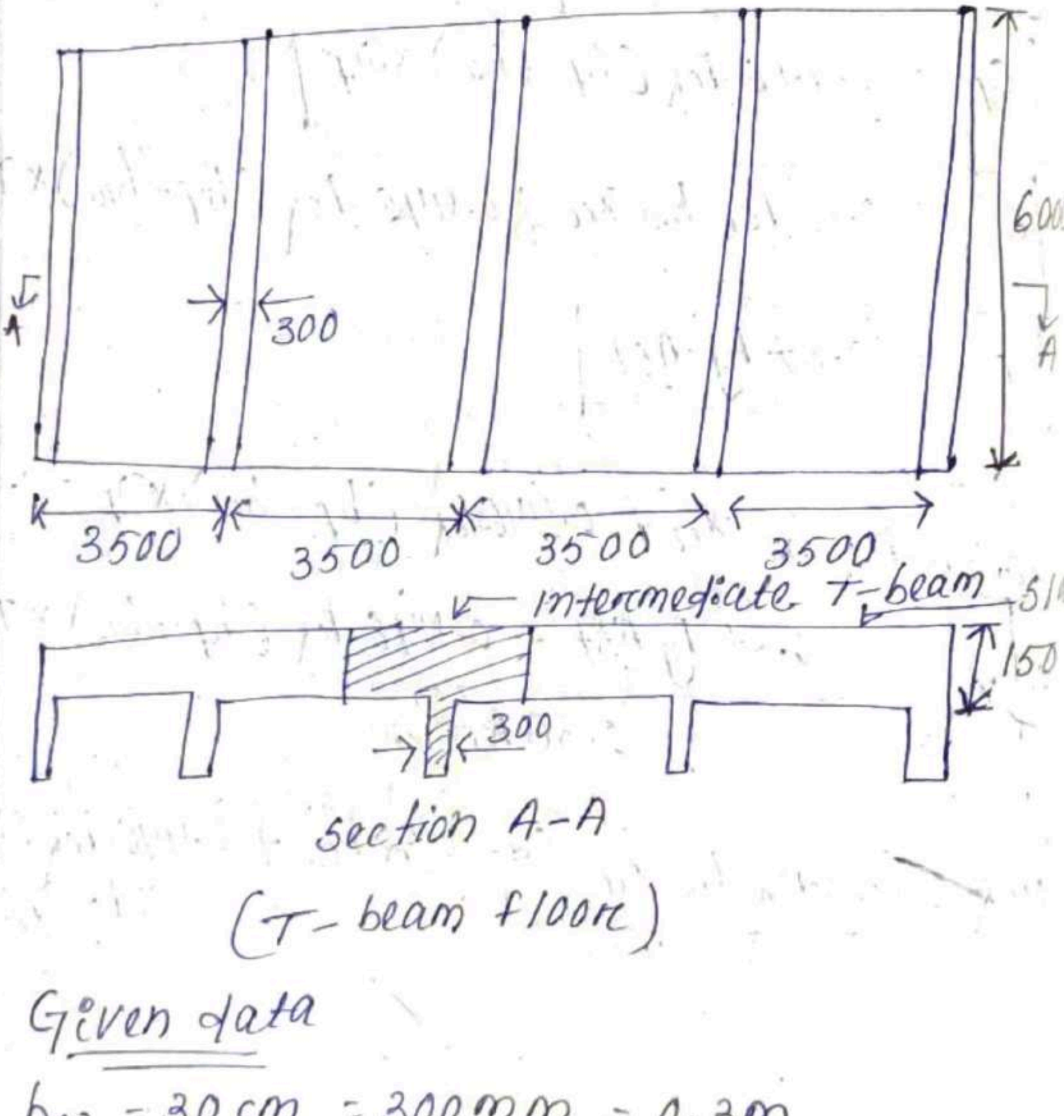
$\Rightarrow 0.36 f_{ck} b_w x_u + 0.446 f_{ck} (b_f - b_w) \times D_f = 0.87 f_y A_{st}$

$$\Rightarrow x_u = \frac{0.87 f_y A_{st} - 0.446 f_{ck} (b_f - b_w) \times D_f}{0.36 f_{ck} b_w}$$

$$MOR = 0.36 f_{ck} b_w x_u (d - 0.42 x_u) + 0.446 f_{ck} (b_f - b_w) \times (d - D_f/2) D_f$$

Problem-1

A T-beam floor consists of 15cm thick RC slab monolithic with 30 cm wide beams. The beams are spaced at 3.5 m centre to centre and their effective span is 6m as shown in fig. If the superimposed load on the slab is 5 kN/m², design an intermediate beam. use M20 mix and Fe 250 grade steel.



section A-A

(T-beam floor)

Given data

$b_w = 30\ cm = 300\ mm = 0.3\ m$

$D_f = 15\ cm = 0.15\ m$ — Assume $D = 400\ mm$

$b_f = 3.5\ m$ $\qquad d' = 40\ mm$

$\qquad d = 360\ mm$

$L_0 = 6\ m$ $\qquad$ depth of web $= 400 - 150 = 250$

Self weight of beam $= b \times d \times 25$

$= 1 \times (0.15) \times 25$

$= 3.75 \; kN/m^2$

Total weight of beam $= w = 5 + 3.75 = 8.75 \; kN/m^2$

Load $= 8.75 \times 3.5 = 30.6 \; kN/m$

$$b_f = \frac{L_0}{6} + b_w + 6D_f$$

$$= \frac{6}{6} + 0.3 + (6 \times 0.15) = 2.2m = 220cm$$

Hence effective width of flange $= 220cm$

Dead load of web beam

= width of web × depth of web × concrete density

$= 0.3 \times 0.25 \times 25 = 1.875 \; kN/m$

~~Total load~~ =

Total load $= 30.6 + 1.875 = 32.475 \; kN/m$

$$BM = \frac{wl^2}{8} = \frac{32.475 \times (6)^2}{8} = 146.13$$

Factor BM $= 1.5 \times 146.13$

$= 219.2 \; kNM$

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

$$= \frac{0.87 \times 250 \times A_{st}}{0.36 \times 20 \times 2200}$$

$= 0.0137 \; A_{st}$

Factored BM = Force of tension × Z

$\Rightarrow 219.2 \times 10^6 = 0.87 f_y A_{st} (d - 0.42 x_u)$

$\Rightarrow 219.2 \times 10^6 = 0.87 \times 250 \times A_{st} (360 - 0.42 \times 0.0137 A_{st})$

$\Rightarrow A_{st} = 2938 mm^2$

$x = \cancel{40}38.19 mm < 150 mm$ (ok)

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

$\Rightarrow 2938 = \frac{\pi}{4} \times 20^2 \times x$

$\Rightarrow x = 10$ nos

A_{st} required

$A_{st} = \frac{\pi}{4} \times 20^2 \times 10$

$= 3141 mm^2$

$(A_{st} = 3141 mm^2 > 2938 mm^2)$ (ok)

minimum reinforcement :-

$\frac{A_{st}}{bd} = \frac{0.85}{f_y}$

$\Rightarrow A_{st} = \frac{0.85 \times b_w \times d}{f_y}$

$\Rightarrow A_{st} = \frac{0.85 \times 300 \times 360}{250} = \cancel{1284}\ 367 mm^2 \nless 3141 m$

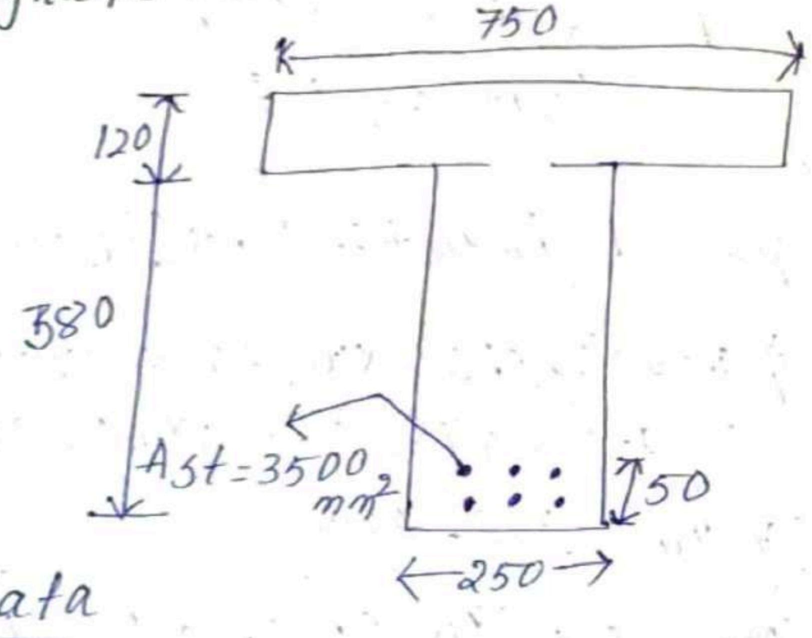
Maximum reinforcement :-

$0.04 b_w D = 0.04 \times 300 \times \cancel{360}400$

$= 4800 mm^2 > 3079 mm^2$

Problem-2

calculate the moment of resistance of a T-beam as shown in fig assuming M20 Mix and Fe415 grade steel.



Given data

$b_f = 750mm$

$D_f = 120mm$

$b_w = 250mm$

$d' = 50mm$

$D = 380 + D_f = 380 + 120 = 500mm$

$d = D - d'$

$= 500 - 50 = 450mm$

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

$f_y = 415\ N/mm^2$

$A_{st} = 3500\ mm^2$

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

$$= \frac{0.87 \times 415 \times 3500}{0.36 \times 20 \times 120} = 234\ mm > D_f$$

$$\frac{D_f}{d} = \frac{120}{450} = 0.27 > 0.20 \text{ mm}$$

$$y_f = 0.15x_u + 0.65D_f$$

$$= (0.15 \times x_u + 78)$$

$$\Rightarrow 0.36 f_{ck} b_w x_u + 0.45 f_{ck}(b_f - b_w) y_f = 0.87 f_y A_{st}$$

$$\Rightarrow 0.36 \times 20 \times 250 \times x_u + 0.45 \times 20 \times (750 - 250) \times (0.15x_u + 78) = 0.87 \times 415 \times 3500$$

$$\Rightarrow x_u = 368.75 \text{ mm}$$

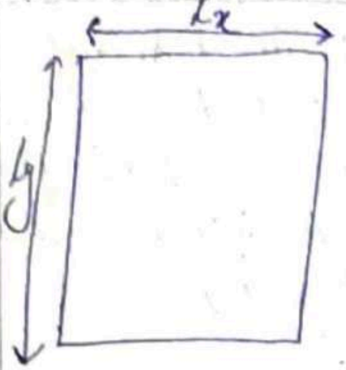
$$M_u = 0.36 \frac{x_u}{d}\left(1 - 0.42\frac{x_u}{d}\right) f_{ck} b_w d^2 + 0.45 \times f_{ck} (b_f - b_w) D_f \left(d - \frac{D_f}{2}\right)$$

$$M_u = 0.36 \times \frac{234}{450}\left(1 - 0.42 \times \frac{234}{450}\right) 20 \times 250 \times (450 + 0.45 \times 20 \times (750 - 250) \times 120\left(450 - \frac{120}{2}\right)$$

$$= 358744464 \text{ Nmm}$$

$$= 358.74 \text{ kNm}$$

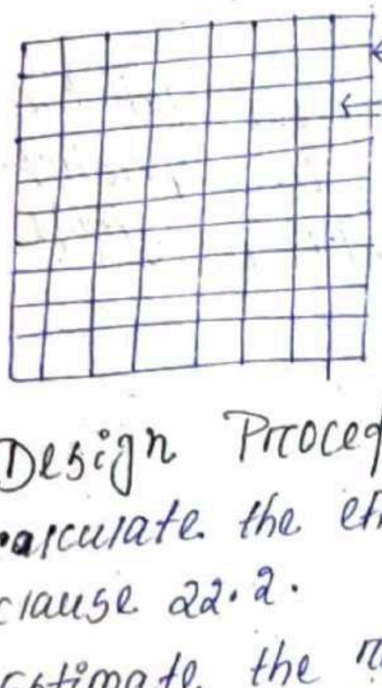
SLABS



l_x = shorter span
l_y = Longer span

$\frac{l_y}{l_x} > 2$ (one-way slab)

$\frac{l_y}{l_x} < 2$ (two-way slab)



main bar
Distribution bar
Distribution bar - 0.15% of reinforcement for HYSD
Distribution bar - 0.12% of reinforcement for Mild

Design Procedure :-

(1) calculate the effective span of slab from clause 22.2.

(2) Estimate the required thickness of slabs as per deflection criteria - clause 23.2

(3) considering 1m wide strip of slab, calculate max. ultimate BM, M_u and SF due to factored load.

4. calculate the depth required from bending assuming the slab as a balanced section if the thickness Provided as per deflection criteria is less Provide the thickness obtained in step 4 and revise the design

5. calculate the main reinforcement and distribution reinforcement.

6. check for cracking:- Both main and distribution steel should not be less than the codal provision for minimum steel.

7. check for shear

8. check for development length

Problem

Design a simple supported roof slab for a 8m X 3.5m clear in size. if the super imposed load is $5 kN/m^2$ use M_{25} and Fe415 grade of steel.

Given data

Longer span = 8m

shorter span = 3.5m

$\omega = 5 \, kN/m^2$

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

$f_y = 415 \, N/mm^2$

$$\frac{\text{Longer span}}{\text{shorter span}} = \frac{8}{3.5} = 2.28 > 2$$

Hence it is a one way slab

Assume modification factor = 1.2

$\frac{L}{d} = 20 \times 1.2$

$\Rightarrow \frac{3.5}{d} = 20 \times 1.2$

$\Rightarrow d = 0.14m$

$= 140mm$

$\simeq 200mm$

Assume,

$\phi = 20mm$

$d' = 15mm$

$D = 200 + 20 + 15$

$= 235\ mm$

$L_{eff} = L + t_s$

$= 3.5 + 200$

$= 203.5mm$

$w_2 = b \times d \times$ unit weight of concrete

$= 1 \times 0.2 \times 25$

$= 5\ kN/m^2$

$S_w = w_1 + w_2$

$= 5 + 5$

$= 10kN/m^2$

$BM = \frac{wl^2}{8}$

$= \frac{10 \times (3.5)^2}{8} = 15.31\ kNm$

$M_u = 0.36 f_{ck}\, x_{umax}\, b(d - 0.42\, x_{umax})$

$\Rightarrow 15.31 \times 10^6 = 0.36 \times 25 \times 0.48d \times 1000 \times (d - 0.42(0.48$

$\Rightarrow d = 66.62\,mm$

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

$\Rightarrow 15.3 \times 10^6 = 0.87 \times 415 \times A_{st} \times 66.62 \times \left(1 - \frac{A_{st} \times 415}{1000 \times 66}\right.$

$\Rightarrow A_{st} = 792.64\,mm^2$

A_{st} min^m $\frac{A_{st}}{bd} = \frac{0.85}{f_y}$

$\Rightarrow \frac{A_{st}}{1000 \times 66.62} = \frac{0.85}{415}$

$\Rightarrow A_{st} = 409.63\,mm^2$

A_{st} $max^m = 0.04 bD$

$= 0.04 \times 200 \times 235$

$= 1880\,mm^2$

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

$\Rightarrow 792.64 = \frac{\pi}{4} \times 20^2 \times x$

$\Rightarrow x = 4$ nos

A_{st} required

$\frac{\pi}{4} \times 20^2 \times 4 = 1256.63\,mm^2$

$S_v = \frac{1000}{\frac{A_{st}}{\frac{\pi}{4}\phi^2}} = \frac{1000}{\frac{1256.63}{\frac{\pi}{4} \times 20^2}} = 250\,mm$

minimum spacing = 3d = 3×66.62 = 199.95 mm

maximum spacing = 300 mm

∴ Provide 20 mm bars @ 300 mm c/c

Design for Distribution bar :—

$A_{st} = 0.12\%\ bD$

$= \frac{0.12}{100} \times 1000 \times 235$

$= 282\ mm^2$

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

$\Rightarrow 282 = \frac{\pi}{4} \times 20^2 \times x$

$\Rightarrow x = 2$ nos

A_{st} required $= \frac{\pi}{4} \times 20^2 \times 2$

$= 628.31\ mm^2$

$$S_v = \frac{1000}{\frac{A_{st}}{\frac{\pi}{4}\phi^2}}$$

$$= \frac{1000}{\frac{628.31}{\frac{\pi}{4} \times 20^2}} = 500\ mm$$

minimum spacing = 5d = 5×66.62 = 333.1 mm

maximum spacing = 450 mm

check for shear :-

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

$$= \frac{15.3 \times 3.5}{2}$$

$$= 26.775 \text{ KN}$$

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

$$= \frac{26.775}{1000 \times 66.62}$$

$$= 0.26 \text{ N/mm}^2$$

$\tau_c =$

$x_1 = 1.00$ $y_1 = 0.62$

$x_2 = 1.25$ $y_2 = 0.67$

$x = 1.09$ $y = ?$

$$y = y_1 + \frac{(y_2 - y_1)(x - x_1)}{(x_2 - x_1)}$$

$$y = 0.62 + \frac{(0.67 - 0.62)(1.09 - 1.00)}{(1.25 - 1.00)}$$

$$y = 0.63 \text{ N/mm}^2$$

$$\tau_c = 0.63 \text{ N/mm}^2$$

$$\tau_c' = 1.00 \text{ N/mm}^2$$

$\tau_v < \tau_c'$ (ok)

check -

$f_s =$

P_{tlim}

$x =$

$x_1 =$

x_2

$y =$

$y =$

y :

K_c

$\frac{spa}{d_{mc}}$

$\frac{SI}{d}$

62
.67

$x - x_1)$

$0.62)(1.09-1.00)$
$5-1.00)$

check for deflection -

$$f_s = 0.58 \times f_y \times \frac{A_{st}\ required}{A_{st}\ Provided}$$

$$= 0.58 \times 415 \times \frac{792.64}{792.64}$$

$$= 240.7$$

$$P_{tlim} = 100\,\frac{A_{st}}{bd}$$

$$= 100 \times \frac{792.64}{1000 \times 66.62}$$

$$= 1.18\,mm$$

$x = 240.7 \quad y_1 = 0.8$

$x_1 = 240 \quad y_2 = 1.2$

$x_2 = 290 \quad y = ?$

$$y = y_1 + \frac{(y_2-y_1)(x-x_1)}{(x_2-x_1)}$$

$$y = 0.8 + \frac{(1.2-0.8)(240.7-240)}{(290-240)}$$

$$y = 0.80$$

$$K_c = 0.80$$

$$\frac{span}{d_{max}} = \frac{span}{d} \times K_c \times K_t \times K_f$$

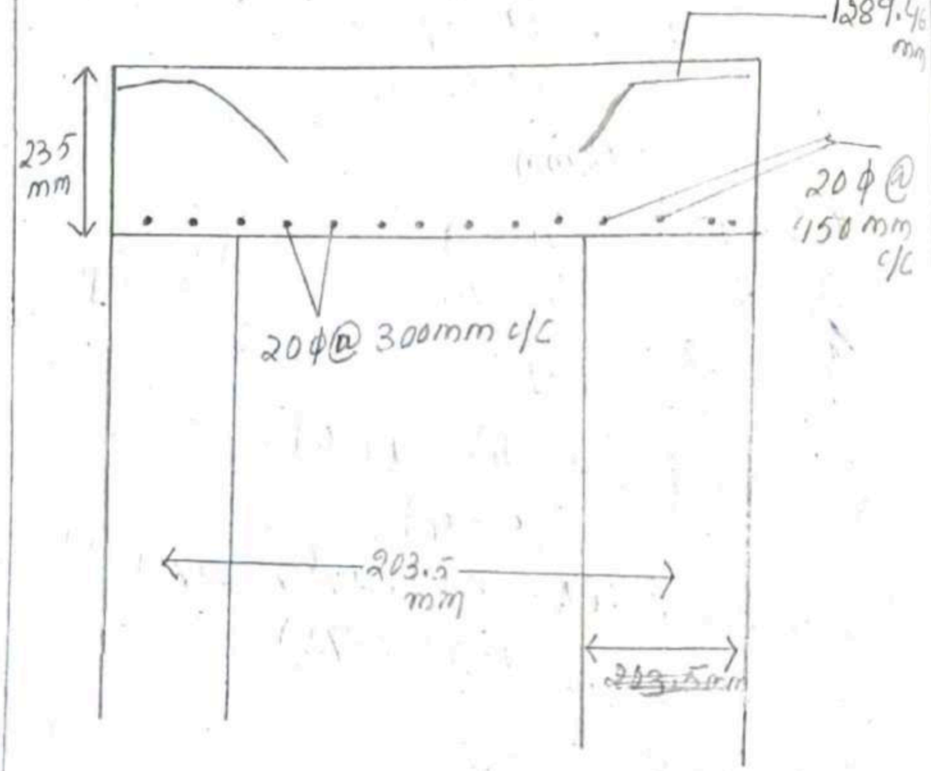
$$\frac{span}{d_{max}} = \frac{20}{66.62} \times 0.80 \times 1 \times 1 = 0.24\ (ok)$$

check for development length :-

$$L_d = \frac{\phi\, 0.87 f_y}{4\, \tau_{bd}}$$

$$= \frac{20 \times 0.87 \times 415}{4 \times 1.4}$$

$$= 1289.46\,mm$$



Problem :-

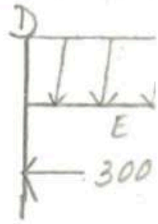
Design a con

three equal s

figure with th

= 2.5 kN/m²,

steel grade =



Solution

Given data :

$L = 3m$

$w_1 = 2.5$

$f_{ck} = 25$

$f_y = 50$

Modification

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

$\Rightarrow \frac{3}{d} = 20.$

$\Rightarrow d = 0.1$

$\Rightarrow d \simeq 20$

Assume ϕ

d

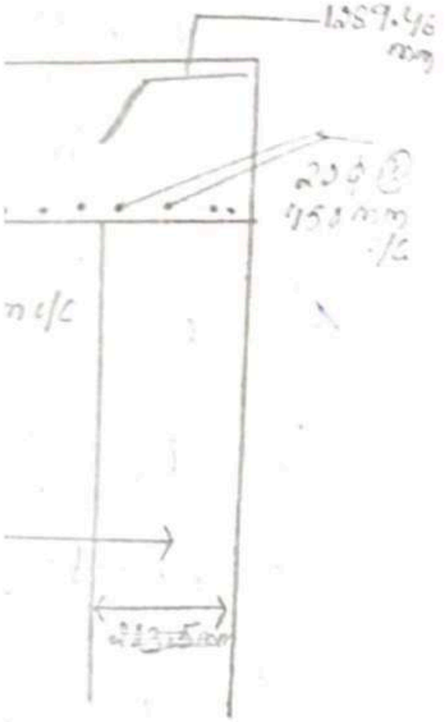
$D = 20$

$=$

...nt length :-

...9.5

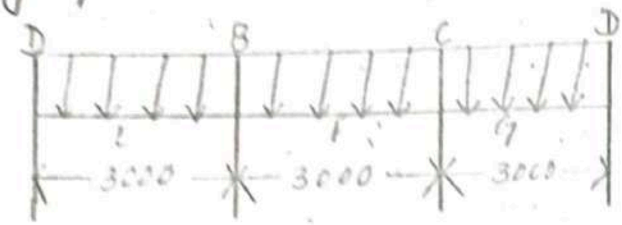
...m



...n c/c

Problem :-

Design a continuous one-way slab having three equal spans of 3m each as shown in figure with the following data : imposed load = 2.5 kN/m², concrete grade = M25 and steel grade = Fe 500D



solution

Given data :-

$l = 3m$

$w_1 = 2.5\ kN/m^2$

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

$f_y = 500\ N/mm^2$

Modification factor = 1.2

$\frac{l}{d} = 20 \times 1.2$

$\Rightarrow \frac{3}{d} = 20 \times 1.2$

$\Rightarrow d = 0.12m = 120mm$

$\Rightarrow d \simeq 200mm$

Assume $\phi = 20mm$

$d' = 15mm$

$D = 200 + 20 + 15$

$= 235mm$

$L_{eff} = L + d$

$= 3 + 0.2$

$= 3.2m$

Assume unit weight of concrete $= 25 kN/m^3$

$w_2 = b \times D \times$ unit weight of concrete

$= 1 \times 0.235 \times 25$

$= 5.875 \; kN/m^2$

$w = w_1 + w_2$

$= 2.5 + 5.875$

$= 8.37 \; kN/m^2$

$BM = \frac{wL^2}{8}$

$= \frac{8.37 \times (3.2)^2}{8}$

$= 10.71 \; kNm$

$m_u = 0.36 f_{ck} \, x_{umax} \, b(d - 0.42 x_{umax})$

$\Rightarrow 10.71 \times 10^6 = 0.36 \times 25 \times 0.46d \times 1000 \times (d - 0.42 \times 0.46d)$

$\Rightarrow d = 56.62 mm$

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

$\Rightarrow 10.71 \times 10^6 = 0.87 \times 500 \times A_{st} \times \cancel{0.46d} \; 56.62 \left(1 - \frac{A_{st} \times}{\cancel{1} \times 56.62 \times 1000}\right.$

$\Rightarrow A_{st} = 536.52 \; mm^2$

A_{st} minimum =

$\frac{A_{st}}{bd} = \frac{0.85}{f_y}$

$\Rightarrow \frac{A_{st}}{1000 \times 56.62} =$

$\Rightarrow A_{st} = 9$

A_{st} maximum

$= 0.04 \, bD$

$= 0.04 \times 1000 \times 2$

$= 9400 mm^2$

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

$\Rightarrow 536.52 = \frac{\pi}{4} \times 20^2$

$\Rightarrow x = 2$ nos.

A_{st} required

$\frac{\pi}{4} \times \phi^2 \times x$

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

$= 628.31 mm^2$

$S_v = \frac{1000}{\frac{A_{st}}{\frac{\pi}{4} \times \phi^2}}$

minimum s

Maximum sp

crete = 25 kN/m^3
crete

$2x_{umax})$

$00 \times (d - 0.42 \times 0.46d)$

$\frac{f_y}{d f_{ck}}\Big)$

$6d - 56.62 \Big(1 - \frac{A_{st} \times 500}{1000 \times 56.62 \times 25}\Big)$

A_{st} minimum =

$$\frac{A_{st}}{bd} = \frac{0.85}{f_y}$$

$$\Rightarrow \frac{A_{st}}{1000 \times 56.62} = \frac{0.85}{500}$$

$$\Rightarrow A_{st} = 96.25 mm^2$$

A_{st} maximum

$= 0.04 BD$

$= 0.04 \times 1000 \times 235$

$= 9400 mm^2$

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

$$\Rightarrow 536.52 = \frac{\pi}{4} \times 20^2 \times x$$

$$\Rightarrow x = 2 nos.$$

A_{st} required

$\frac{\pi}{4} \times \phi^2 \times x$

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

$= 628.31 mm^2$

$$S_v = \frac{1000}{\frac{A_{st}}{\frac{\pi}{4} \times \phi^2}} = \frac{1000}{\frac{628.31}{\frac{\pi}{4} \times 20^2}} = 500 mm$$

minimum spacing $= 3d = 3 \times 56.62 = 169.86$ mm

Maximum spacing = 300 mm

Provide 20mm bar @ 300mm c/c.

Design for distribution bar :-

$A_{st} \overset{\cancel{0.12}}{=} 0.12\% \, bD$

$= \frac{0.12}{100} \times 1000 \times 235$

$= 282 \, mm^2$

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

$\Rightarrow 282 = \frac{\pi}{4} \times 20^2 \times x$

$\Rightarrow x = 2nos$

A_{st} required

$\frac{\pi}{4} \times 20^2 \times 2 = 628.31 mm^2$

$S_v = \frac{1000}{\frac{A_{st}}{\frac{\pi}{4} \times \phi^2}} = \frac{1000}{\frac{628.31}{\frac{\pi}{4} \times 20^2}} = 500 mm$

minimum spacing $= 5d = 5 \times 56.62 = 283.1 mm$

maximum spacing $= 450 mm$

Provide 20mm @ 450 mm c/c.

check for shear

$V_u = \frac{wl}{2} = \frac{8.37 \times 3}{2} = 12.55 \, kN$

$\tau_v = \frac{V_u}{bd} = \frac{12.55}{1000 \times \cancel{60.14} \, 56.62} = 0.22 \, N/mm^2$

$x_1 = 1.00 \quad y_1 = 0.62$

$x_2 = 1.25 \quad y_2 = 0.67$

$x = 1.09 \quad y = ?$

$y = y_1 + \frac{(y_2 -}{(x}$

$y = 0.62 +$

$y = 0.63 N/m$

$\tau_c = 0.63 N/$

$\tau_c' = 1.00 N/$

$\tau_v < \tau_c'$ (co

check for de

$f_s = 0.58 f_y$

$= 0.58 \times 5$

$= 290$

$P_t lim = 100 -$

$= 100 \times -$

$= 1.10$

$x = 240.7$

$x_1 = 240$

$x_2 = 270$

$y = 0.8 + \frac{(1.}{}$

$y = 0.80$

$K_c = 0.80$

m c/c.
n bar :-

$\frac{1}{5}00mm$

$\times 56.62 = 283.1 mm$

m

c/c.

55 kN

$= 0.22 N/mm^2$

$$y = y_1 + \frac{(y_2 - y_1)(x - x_1)}{(x_2 - x_1)}$$

$$y = 0.62 + \frac{(0.67-0.62)(1.07-1.00)}{(1.25-1.00)}$$

$y = 0.63 N/mm^2$

$\tau_c = 0.63 N/mm^2$

$\tau_c' = 1.00 N/mm^2$

$\tau_v < \tau_c'$ (ok)

check for deflection.

$$f_s = 0.58 f_y \times \frac{A_{st} \text{ required}}{A_{st} \text{ provided}}$$

$$= 0.58 \times 500 \times \frac{628.31}{628.31}$$

$= 290$

$$Pt\,lim = 100 \frac{A_{st}}{bd}$$

$$= 100 \times \frac{628.31}{1000 \times 56.62}$$

$= 1.10 mm$

$x = 240.7$ $y_1 = 0.8$

$x_1 = 240$ $y_2 = 1.2$

$x_2 = 270$ $y = ?$

$$y = 0.8 + \frac{(1.2-0.8)(240.7-240)}{(270-240)}$$

$y = 0.80$

$K_c = 0.80$

$$\frac{span}{d_{max}} = \frac{span}{d} \times k_c \times k_f \times k_t$$

$$\frac{span}{d_{max}} = \frac{20}{56.62} \times 0.80 \times 1 \times 1$$

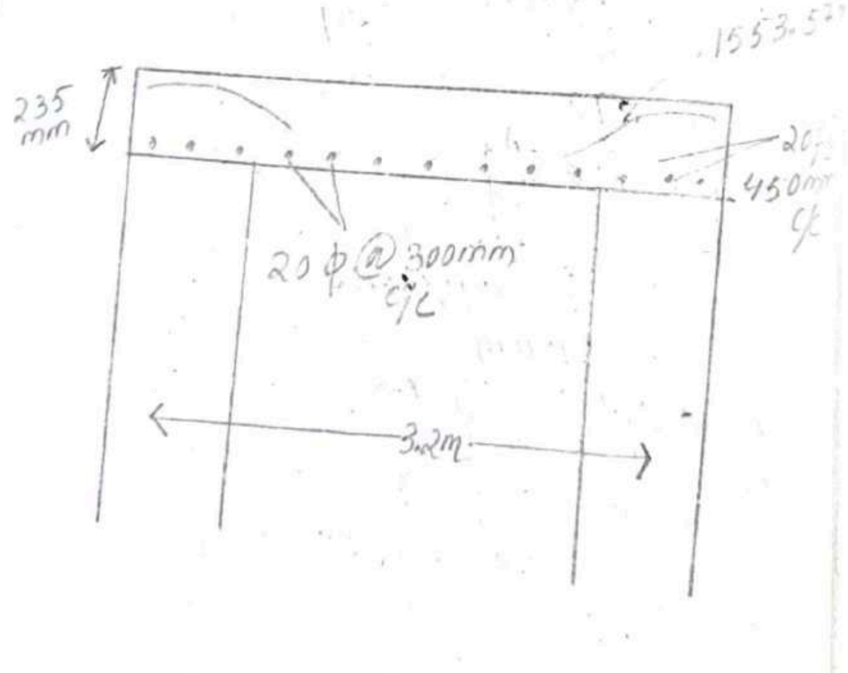
$$\frac{span}{d_{max}} = 0.282 \text{ (OK)}$$

check for development length:-

$$L_d = \frac{\phi \, 0.87 f_y}{4 \tau_{bd}}$$

$$= \frac{20 \times 0.87 \times \cancel{415}\ 500}{4 \times 1.4}$$

$$= 1553.57 \text{ mm}$$



TWO-WAY SLAB:

1- check if the sla[...] by checking $\frac{l_y}{l_x}$ [...]

if $\frac{l_y}{l_x} \leq 2$ [...]

2- Estimate the [...] deflection criteria [...]

→ If $l_x > 3.5$ m [...]

$$\boxed{d = \frac{span}{d \times m} \ldots}$$

where, mf = 1.4 [...]

→ if $l_x \leq 3.5$m [...]

$$\boxed{D = \frac{span}{35} \ldots}$$

$$\boxed{D = \frac{span}{35 \times 0.8} \ldots}$$

$$d = D - \frac{\phi}{2} - \ldots$$

3- Find the effective [...]

4- calculate the load [...]

5- calculate the Ma[...] direction.

$$\boxed{M_x = \alpha_x w l_x^2}$$

$$\boxed{M_y = \alpha_y w l_x^2}$$

TWO-WAY SLAB:-

1- check if the slab is one way or two way slab by checking $\frac{l_y}{l_x}$.

if $\frac{l_y}{l_x} \le 2$ (two way slab)

2- Estimate the ~~Eq~~ required slab thickness as per deflection criteria.

→ If $l_x > 3.5$ m and/or live load $> 3 kN/m^2$

$$\boxed{d = \frac{span}{d \times mf}}$$

where, $mf = 1.4 - 1.5$

→ if $l_x \le 3.5$m and/or, live load $\le 3 kN/m^2$

$$\boxed{D = \frac{span}{35}}$$ for Fe250

$$\boxed{D = \frac{span}{35 \times 0.8}}$$ for HYSD bars

$$d = D - \frac{\phi}{2} - \text{clear cover}$$

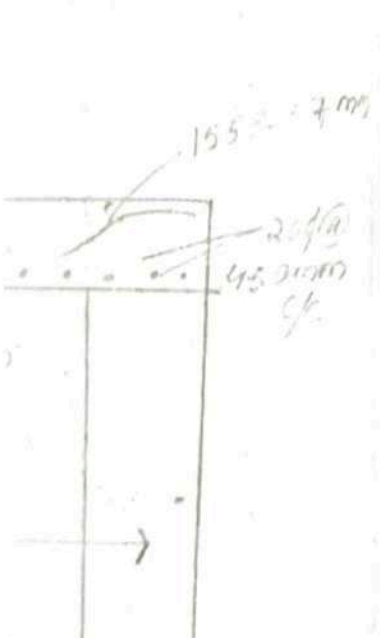
3- Find the effective span

4- calculate the loads on the slab

5- calculate the Max. BM per unit weight direction.

$$\boxed{M_x = \alpha_x w l_x^2}$$

$$\boxed{M_y = \alpha_y w l_x^2}$$



Design step

1- Given data

2- check one way, two way slab

$$\frac{\text{Longer span } (L_y)}{\text{shorter span } (L_x)} < 2 \text{ (two way slab)}$$

3- calculate effective depth

$$\frac{l}{d} = \text{basic value} \times \text{Modification factor}$$
(37 page) (1.2-1.5)

4- calculate $D = d + \frac{\phi}{2} + d'$ ($d' = 15-20$)

5- calculate span of the slab L_y, L_x

span = clear span + t_s

span = clear span + d

6- Load calculation ($b \times d \times$ unit weight of concrete

7- moment calculation

calculate $\frac{L_y}{L_x}$

then calculate α_x, α_y (page no-91)
(table-27)

$M_x = \alpha_x w l_x^2$

$M_y = \alpha_y w L_x^2$ (page-91)

calculate d for maximum BM

$M = 0.36 f_{ck} x_{umax} b (d - 0.42 x_{umax}) \Rightarrow d = ?$

10- calculation of

calculate A

$M_x = 0.87$

$A_{stx} = ?$

spacing (S_v

$M_y = 0.87$

$A_{sty} = ?$

spacing (S_v

11- shear check

12- development

slab

(two way slab)

th

odification factor
(1.2-1.5)

d' (d' = 15-20)
lab Ly, Lx

unit weight of concrete)

(page no - 91)
(table-27)

91)

mum BM
0.42 x_{umax}) ⇒ d = ?

10- calculation of area of steel
calculate Ast from (96 page)

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

$A_{stx} = ?$

$$\text{spacing } (S_v) = \frac{1000}{\frac{A_{stx}}{\frac{\pi}{4}\phi^2}}$$

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

$A_{sty} = ?$

$$\text{spacing } (S_v) = \frac{1000}{\frac{A_{sty}}{\frac{\pi}{4}\phi^2}}$$

11- shear check
12- development length check

Problem-1

Design a two-way slab for a room 5.5m x ... clear in size if the superimposed load is $5 kN/m^2$. Use M_{25} mix and Fe415 grade steel.

(a) edges simply supported - corners not held down.

(b) edges simply supported - corners held down.

Solution

Given data :-

$w_1 = 5 \ kN/m^2$

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

$f_y = 415 N/mm^2$

$\frac{L}{d}$ = Basic value x modification Factor

$\Rightarrow \frac{4}{d} = 20 \times 1.2$

$\Rightarrow d = 0.166m \simeq 200mm$

Assume,

effective cover (d') = 20mm

bar diameter (ϕ) = 20mm

$D = d + d' + \frac{\phi}{2}$

$= 200 + 20 + \frac{20}{2}$

$= 230mm$

Longer span = clear span + d

$L_y = 5.5 + 0.2$

$= 5.7m$

Shorter span

$L_x = 4 + 0.2$

Assume,

unit weight

$w_2 = b \times D \times$

$= 1 \times 0.2$

$= 5.75$

$w = w_1 + w_2$

$= 5 + 5.7$

$= 10.75$

$\frac{L_y}{L_x} = \frac{5.7}{4.2}$

$x = 1.35 \quad y =$

$x_1 = 1.3 \quad y_1 =$

$x_2 = 1.4 \quad y_2 =$

$y = y_1 + \frac{(y_2 -}{(x}$

$y = 0.093 + ($

$y = 0.096$

$\alpha_x = 0.096$

$x = 1.35 \quad y =$

$x_1 = 1.3 \quad y_1 =$

$x_2 = 1.4 \quad y_2 =$

$y = 0.055 + ($

a room 5.5m X 4.0m
posed load is
grade steel.

ers not held down
rs held down.

ation Factor

mm
mm

td

shorter span

$L_x = 4 + 0.2 = 4.2m$

Assume,

unit weight of concrete = $25 kN/m^3$

$w_2 = b \times D \times$ unit weight of concrete

$= 1 \times 0.23 \times 25$

$= 5.75 kN/m^2$

$w = w_1 + w_2$

$= 5 + 5.75$

$= 10.75 kN/m^2$

$\frac{L_y}{L_x} = \frac{5.7}{4.2} = 1.35$

$x = 1.35 \quad y = ?$

$x_1 = 1.3 \quad y_1 = 0.093$

$x_2 = 1.4 \quad y_2 = 0.099$

$$y = y_1 + \frac{(y_2 - y_1)(x - x_1)}{(x_2 - x_1)}$$

$$y = 0.093 + \frac{(0.099 - 0.093)(1.35 - 1.3)}{1.4 - 1.3}$$

$y = 0.096$

$\alpha_x = 0.096$

$x = 1.35 \quad y = ?$

$x_1 = 1.3 \quad y_1 = 0.055$

$x_2 = 1.4 \quad y_2 = 0.051$

$$y = 0.055 + \frac{(0.051 - 0.055)(1.35 - 1.3)}{1.4 - 1.3}$$

$y = 0.053$

$\alpha_y = 0.053$

Moment of resistance at shorter span:-

$M_x = \alpha_x w l_x^2$

$= 0.096 \times 10.75 \times (4.2)^2$

$= 18.2$ kNm

$M_y = \alpha_y w l_x^2$

$= 0.053 \times 10.75 \times (4.2)^2$

$= 10.05$ kNm

$BM = \frac{wl^2}{8}$

$= \frac{10.75 \times (4)^2}{8}$

$= 21.5$ kNm

$M = 0.36 f_{ck} x_{umax} b (d - 0.42 x_{umax})$

$\Rightarrow 18.2 \times 10^6 = 0.36 \times 25 \times 0.48d \times 1000 \times 0.48d - 0.4$

$\Rightarrow d = 133$ mm

$M_x = 0.87 f_y A_{stx} d \left(1 - \frac{A_{stx} f_y}{bd f_{ck}}\right)$

$\Rightarrow 18.2 \times 10^6 = 0.87 \times 415 \times A_{stx} \times 133 \times \left(1 - \frac{A_{stx} \times 415}{1000 \times 133 \times 2}\right.$

$\Rightarrow A_{stx} = 398.86 mm^2$

spacing (S_v) =

use 20mm bar

$m_y = 0.87 f_y A_{sty}$

$\Rightarrow \cancel{10.05 \times 10^6} = 0.87$

$M = 0.36 f_{ck} x_{u}$

$\Rightarrow$

$m_y = 0.87 f_y A_{sty}$

$\Rightarrow 10.05 \times 10^6 = 0.8$

$\Rightarrow A_{sty} = 215.06$

spacing (S_v) =

use 20mm bar

shorter span:-

$(4.2)^2$

$(4.2)^2$

$d - 0.42\, x_{umax})$

$d \times 1000 \times 0.48d - 0.42 \times 0.48d$

$\dfrac{A_{stx} f_y}{b d f_{ck}})$

$A_{stx} \times 133 \times (1 - \dfrac{A_{stx} \times 415}{1000 \times 133 \times 25})$

spacing $(S_v) = \dfrac{1000}{\dfrac{A_{stx}}{\frac{\pi}{4} \times \phi^2}} = \dfrac{1000}{\dfrac{398.86}{\frac{\pi}{4} \times \phi^2}} = 787.64\,mm$

use 20mm bar @ 200mm c/c

$\cancel{M_y = 0.87 f_y A_{sty}\, d \left(1 - \dfrac{A_{sty} f_y}{b d f_{ck}}\right)}$

$\Rightarrow \cancel{10.05 \times 10^6 = 0.87 \times 415 \times A_{sty} \times 108.54}$

$\cancel{M = 0.36 f_{ck}\, x_{umax}\, b (d - 0.42\, x_{umax})}$

$\Rightarrow M_y = 0.87 f_y A_{sty}\, d \left(1 - \dfrac{A_{sty} f_y}{b d f_{ck}}\right)$

$\Rightarrow 10.05 \times 10^6 = 0.87 \times 415 \times A_{sty} \times 133 \left(1 - \dfrac{A_{sty}\, 415}{1000 \times 133 \times 25}\right)$

$\Rightarrow A_{sty} = 215.06\,mm^2$

spacing $(S_v) = \dfrac{1000}{\dfrac{A_{sty}}{\frac{\pi}{4} \times \phi^2}} = \dfrac{1000}{\dfrac{215.06}{\frac{\pi}{4} \times 20^2}}$

$= 1460.79\,mm$

use 20mm bar @ 200mm c/c.

check for shear:-

$$V_u = \frac{wl}{2}$$
$$= \frac{10.75 \times 4}{2}$$
$$= 21.5 \text{ kN}$$

$$\tau_v = \frac{V_u}{bd}$$
$$= \frac{21.5 \times 10^3}{1000 \times 133}$$
$$= 0.16 \text{ N/mm}^2$$

$$\tau_c = 0.29 \text{ N/mm}^2$$

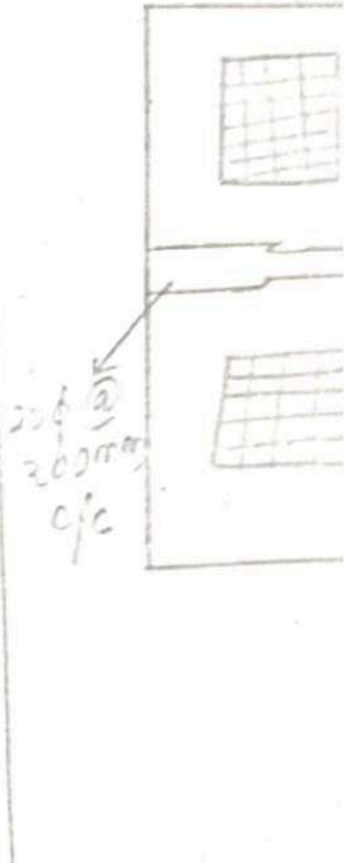
$$\tau_c' = \tau_c k$$
$$= 0.29 \times 1.2$$
$$= 0.34 \text{ N/mm}^2$$

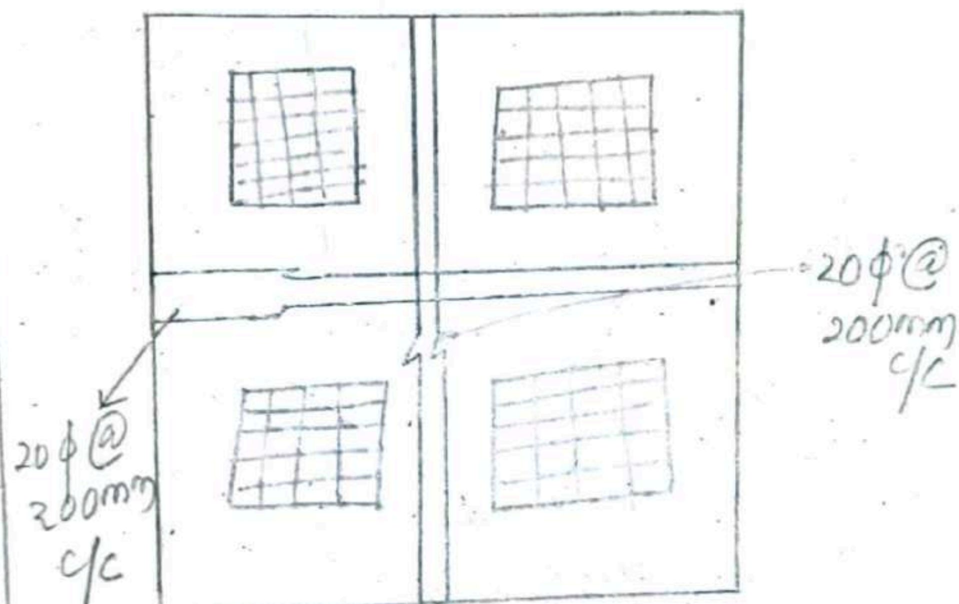
$\tau_v < \tau_c'$ (ok)

check for development length -

$$L_d = \frac{\phi\, 0.87 f_y}{4 \tau_{bd}}$$
$$= \frac{20 \times 0.87 \times 415}{4 \times 1.4}$$

$$= 1289.46 \text{ mm}$$



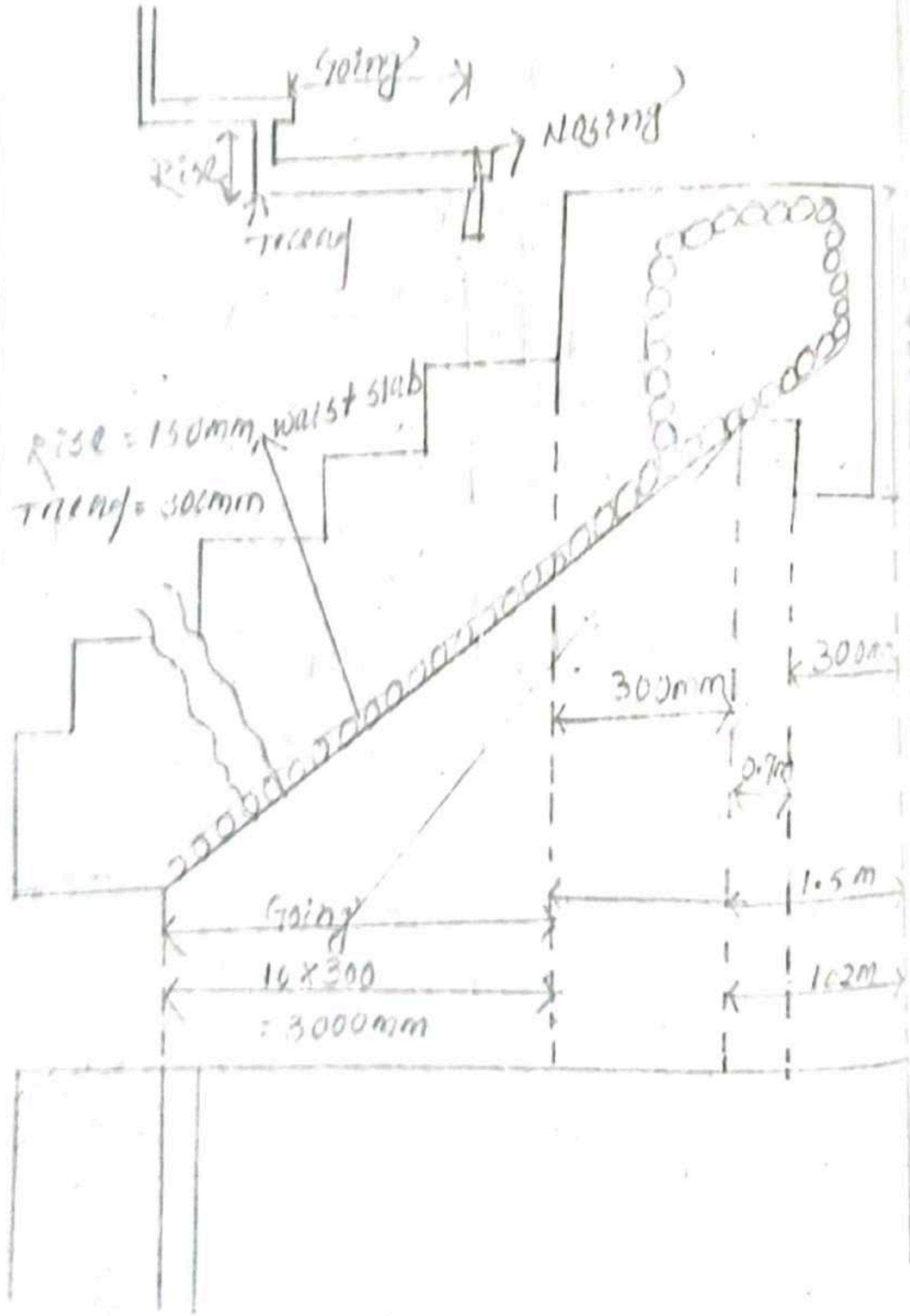


20ϕ @ 200mm c/c
20ϕ @ 200mm c/c

STAIRCASE

(i) For the easy moment from one floor to another floor, when be constructed a structural member that member is known as staircase.

(ii) To main component are tread and rise.



from one floor to
constructed a structural
two as staircase.

tread and rise.

Problem:-

Design a straight staircase structurally independent of Rise side 150mm and the size of tread is 300mm the width of the tread is 1.5m the live load $3 kN/m^2$ and floor finish load $1.5 kN/m^2$. design staircase useing M20 and Fe415.

Given data

$R = 150mm$

$T = 300mm$

$b = 1.5m = l$

$w_1 = 3 kN/m^2$

$w_2 = 1.5 kN/m^2$

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

$f_y = 415 N/mm^2$

Assume thickness of waist slab $(D) = 125mm$

~~Load calculation~~

self weight of the waist slab.

$S_w = 1.5 \times 0.125 \times 25$

$= 4.68 kN/m$

self weight thead & rise

$= 25 \times 0.3 \times 0.15$

$= 1.125 kN/m$

$w = 3 + 1.5 + 4.68 + 1.125$

$= 10.305 kN/m$

Factor load $= 1.5 \times 10.305$

$= 15.457 kN/m$

$$BM = \frac{wl^2}{8}$$

$$= \frac{15.457 \times (1.5)^2}{8}$$

$$= 4.347 \, kNm$$

Assume, $b = 1000\,mm$

effective depth $(d) = D - d'$

$$= 125 - 20$$

$$= 105\,mm$$

Main reinforcement

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

$$\Rightarrow 4.347 \times 10^6 = 0.87 \times 415 \times A_{st} \times 105 \left(1 - \frac{A_{st} \times 415}{1000 \times 105 \times 20}\right)$$

$$\Rightarrow A_{st} = 117.38\,mm^2$$

Assume bar diameter $(\phi) = 20\,mm^2$

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

$$\Rightarrow 117.38 = \frac{\pi}{4} \times 20^2 \times x$$

$$\Rightarrow x = 2\,nos$$

A_{st} required

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

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

$$= 628.31\,mm^2$$

Spacing (S_v) =

Provide 2-20m

Distribution r

$A_{st} = 0.12\%$ b

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

$= 150\,mm$

Assume bar

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

$\Rightarrow 150 = \frac{\pi}{4} \times 12^2 \times$

$\Rightarrow x = 2\,nos$

A_{st} required

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

$\Rightarrow A_{st} = \frac{\pi}{4} \times 12^2$

$= 226.1$

Spacing $= \frac{1000}{A_{st}}$

$\frac{\pi}{4} \times$

Provide 2-12

$$\text{spacing } (S_v) = \frac{1000}{\frac{A_{st}}{\frac{\pi}{4}\phi^2}} = \frac{1000}{\frac{628.31}{\frac{\pi}{4}\times 20^2}}$$

$$= 500mm > 300mm$$

Provide 2-20mm @ 300mm c/c

Distribution reinforcement

$A_{st} = 0.12\%\ bD$

$= \frac{0.12}{100} \times 1000 \times 125$

$= 150\ mm^2$

$\times 415$
$\times 105 \times 20)$

Assume bar diameter $(\phi) = 12mm$

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

$\Rightarrow 150 = \frac{\pi}{4} \times 12^2 \times x$

$\Rightarrow x = 2$ nos

A_{st} required

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

$\Rightarrow A_{st} = \frac{\pi}{4} \times 12^2 \times 2$

$= 226.19\ mm^2$

$$\text{spacing} = \frac{1000}{\frac{A_{st}}{\frac{\pi}{4}\times\phi^2}} = \frac{1000}{\frac{226.19}{\frac{\pi}{4}\times 12^2}} = 500mm > 300mm$$

Provide 2-12 @ 300 mm c/c

check shear

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

$= \frac{4.347 \times 1.5}{2}$

$= 3.26\,kN$

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

$= \frac{3.26 \times 10^3}{1000 \times 105}$

$= 0.03$

$P_{tlim} = 100 \times \frac{A_{st}}{bd}$

$= 100 \times \frac{226.19}{1000 \times 105}$

$= 0.21$

$\tau_c = x = 0.21 \quad y = ?$

$x_1 = 0.15 \quad y_1 = 0.28$

$x_2 = 0.25 \quad y_2 = 0.36$

$$y = y_1 + \frac{(y_2 - y_1)(x - x_1)}{(x_2 - x_1)}$$

$$y = 0.28 + \frac{(0.36 - 0.28)(0.21 - 0.15)}{0.25 - 0.15}$$

$y = 0.32$

$\tau_c = 0.32 \quad \therefore \tau_v > \tau_c$ (ok)

?

.28

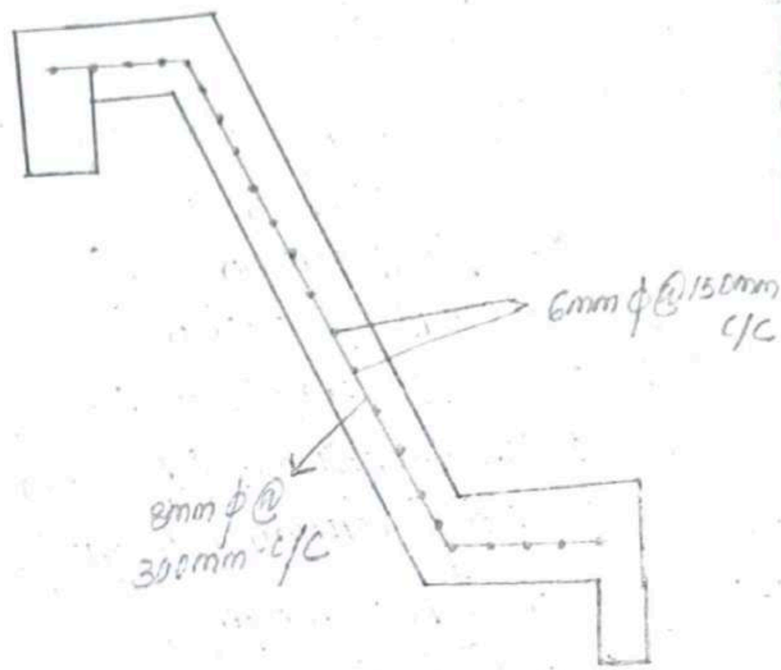
0.36

$(-x_1)$

$)$

$0.28)(0.21-0.15)$

$25-0.15$



$v > \tau_c$ (ok)

COLUMN:

classification of column :-

1. Based on shape -
   1- square
   2- Rectangular
   3- circular

2- Based on type of reinforcement :-
   1- Tied column
   2- spiral column
   3- composite column

3- Based on slenderness ratio :- $\left(\frac{l}{r}\right)$
   1- short column $\left(\frac{L}{D} \leq 12\right)$
   2- Long column $\left(\frac{L}{D} > 12\right)$

4- Based on types bending :-
   1- Axially loaded column
   2- column with axially loaded and uniaxial bending
   3- column with axially loaded and biaxial bending

slenderness ratio (λ) :- (l/r)

$$= \frac{\text{effective length } (l)}{\text{least radius of gyration } (r)}$$

$\frac{L_{eff}}{D} > 3$ (column)

< 3 (Pedisteral)

slenderness rati

Max. slenderness

* for cantilever

Minimum Eccentr

$$\boxed{e_{min} = \frac{\text{unsupp}}{5}}$$

$$\boxed{e_{min} = 20 \text{ mm}}$$

maximum . Eccentr

$$\boxed{e_{max} = 0.05 BD}$$

or

$$\boxed{e_{max} = 30 \text{ mm}}$$

Reinforcement :-

→ min. percentage o

→ max. percentage of

→ min. diameter of bar

:-

orcument :-

n

ratio :- $\left(\frac{l}{r}\right)$

$\left(\frac{l}{D} \leq 12\right)$

$\left(\frac{l}{D} > 12\right)$

g :-

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ally loaded and

) :- (l/r)

gth (l)

of gyration (r)

umn)

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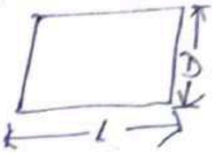
Slenderness ratio :-

Max. slenderness ratio = $\frac{\text{unsupported length}}{\text{least lateral dimension}} \leq 60$

* for cantilever column - unsupported length $\leq \frac{100b^2}{D}$



Minimum Eccentricity :- (e)

$$\boxed{e_{min} = \frac{\text{unsupported length}}{500} + \frac{D}{30}}$$

or (which is lesser one)

$$\boxed{e_{min} = 20mm}$$

Maximum Eccentricity :-

$$\boxed{e_{max} = 0.05\,BD}$$

or

$$\boxed{e_{max} = 30\,mm}$$

Reinforcement :-

→ min. percentage of steel = 0.8% of BD

→ max. percentage of steel = 4% of BD (for lapped bars)

= 6% of BD (for mulded / coupling bars)

→ min. diameter of bars = 12mm

→ max. spacing of reinforcement = 300mm

→ min. cover = 40mm

→ min. no. of bars in columns → Rectangular = 4, Circular = 6

Transverse Reinforcement :—

→ Diameter of ties > $\frac{1}{4}$ of largest dia of min bar. or 6mm (which ever is greater)

spacing of bars :—

It should not be greater than min. of the following :—

(a) least lateral dimenssion

(b) 16 × dia of smallest longitudinal bar

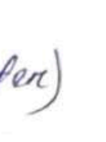
(c) 300 mm

Design strength of column :—

$$\boxed{P_u = \sigma_c A_c + \sigma_s A_{sc}}$$

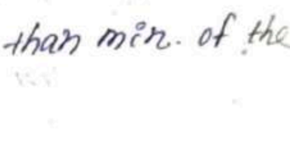
$$\boxed{\begin{aligned} Fe250 &= 0.87 f_y \\ Fe415 &= 0.79 f_y \\ Fe500 &= 0.75 f_y \end{aligned}}$$

$= 0.446 f_{ck} (A_g - A_{sc}) + 0.75 f_y \times A_{sc}$



$= 0.446 f_{ck} A_g - 0.446 f_{ck} A_{sc} + 0.75 f_y A_{sc}$

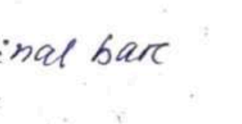
$= \boxed{0.446 f_{ck} A_g + 0.75 f_y A_{sc}}$



(For "0" eccentricity)

for the value of eccentricity :—

$$\boxed{P_u = 0.4 f_{ck} A_g + 0.67 f_y A_{sc}}$$



Design a rectang[...]
400 × 600 mm to s[...]
2000kN. the unsu[...]
3m. the column i[...]
again rotation t[...]

Given data

$b = 400mm$

$D = 600mm$

$l = 3m$

$P_u = 2000kN$

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

$f_y = 415 N/mm^2$

$L_{eff} = 0.65 \times$ [...]

$= 0.65 \times$ [...]

$= 1.95$ [...]

$\frac{L_{eff}}{D} = \frac{1.9[...]}{0.[...]}$

∴ Hence it is a[...]
unsupported lengt[...]

500

$= \frac{1.95}{500} + \frac{0.6}{30}$

$= 0.0239 = 23mm$

nt = 300mm

ns } Rectangular = 4
circular = 6

: —

largest dia of min
or 6mm
ever is greater)

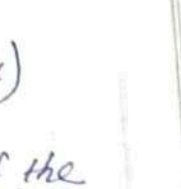
ater than min. of the

ion
ongitudinal bar

olumn : —

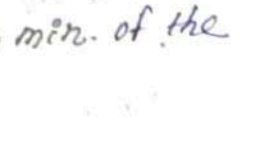
$\boxed{\begin{array}{l} Fe250 = 0.87f_y \\ fe415 = 0.79 f_y \\ Fe500 = 0.75 f_y \end{array}}$

+ $0.75 f_y \times A_{sc}$.



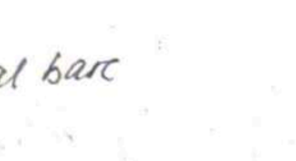
$A_{sc} + 0.75 f_y A_{sc}$.

A_{sc}

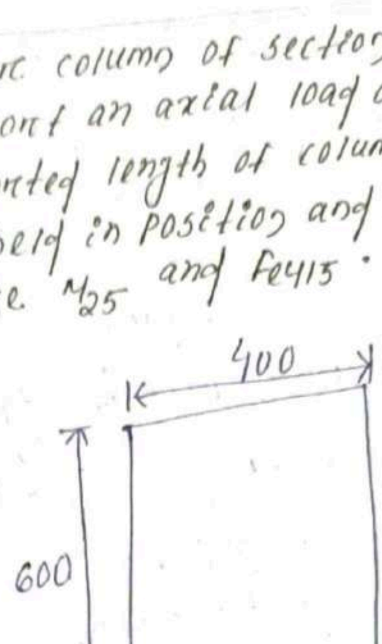


city)
centricity : —

67 fy Asc



Design a rectangular column of section 400 x 600 mm to support an axial load of 2000kN. the unsupported length of column is 3m. the column is held in position and restrain again rotation take M_{25} and Fe415.



Given data

$b = 400mm$

$D = 600 mm$

$l = 3m$

$P_u = 2000kN$

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

$f_y = 415 \ N/mm^2$

$L_{eff} = 0.65 \times l$
$= 0.65 \times 3$
$= 1.95 \ m$

$\frac{L_{eff}}{D} = \frac{1.95}{0.6} = 3.25 < 12$

∴ Hence it is an short column.

$\frac{\text{unsupported length of column}}{500} + \frac{D}{30}$

$= \frac{1.95}{500} + \frac{0.6}{30}$

$= 0.0239 = 23mm$

Maximum eccentricity :-

$e_{max} = 0.05 \times B \times D$
$= 0.05 \times 0.4 \times 0.6$
$= 0.012$
$= 12 mm$

$\therefore$ Here eccentricity = 23mm

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

$A_g = 400 \times 600$
$= 240000 \ mm^2$

Factor load $= 1.5 \times 2000$
$= 3000 kN$

$\Rightarrow 3000 \times 10^3 = 0.4 \times 25 \times (A_g - A_{sc}) + 0.67 \times 415$

$\Rightarrow A_{sc} = 2238.38 \ mm^2$

Assume, $\phi = 16$ mm

$A_{sc} = \frac{\pi}{4} \times \phi^2 \times x$

$\Rightarrow 2238.38 = \frac{\pi}{4} \times (16)^2 \times x$

$\Rightarrow x = 12$ nos

spacing $= \frac{D - 2 \times d'}{5}$

$= \frac{600 - 2 \times 50}{5} = 100mm$

(Q) Design a square
21000kN $l = 3m$,

Given data

$P_u = 21000 kN$

$l = 3m$

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

$f_y = 415 N/mm^2$

$\frac{A_g}{A_{sc}} = 1\%$

$\Rightarrow A_{sc} = \frac{1\%}{A_g}$

$\Rightarrow A_{sc} = 0.01 A_g$

$A_c = A_g - A_{sc}$

Factored load =

$P_u = 0.4 f_{ck} A_c +$

$\Rightarrow 31500 \times 10^3 = 0.4 \times$

$\Rightarrow A_g = 2943787$

$a^2 = 2943787$

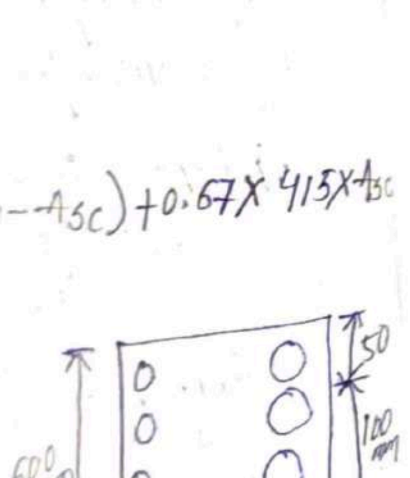
$a = \sqrt{2943787}$

$= 1715.$

$\simeq 1720 mm$

mm

$-A_{sc})+0.67\times415\times A_{sc}$



$=100mm$

(Q) Design a square column to carry a load of 21000kN $l=3m$, $f_{ck}=20\,N/mm^2$, $f_y=415\,N/mm^2$

<u>Given data</u>

$P_u = 21000\,kN$

$l = 3m$

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

$f_y = 415\,N/mm^2$

$\frac{A_g}{A_{sc}} = 1\%$

$\Rightarrow A_{sc} = \frac{1\%}{\cancel{A_g}} \quad \frac{A_g}{1\%}$

$\Rightarrow A_{sc} = 0.01\,A_g$

$A_c = A_g - A_{sc}$

Factored load $= 1.5\times21000$
$= 31500\,kN$

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

$\Rightarrow 31500\times10^3 = 0.4\times20\times(A_g - 0.01\,A_{sc}) + 0.67\times415\times0.01\,A_g$

$\Rightarrow A_g = 2943787.67\,mm^2$

$a^2 = 2943787.67$

$a = \sqrt{2943787.67}$

$= 1715.74\,mm$

$\cong 1720\,mm$

A_g Provided $= (1720)^2$

$= 2958400 mm^2$

$A_{sc} = 0.01 \times 2958400$

$= 29584\ mm^2$

Assume $\phi = 40mm$

$A_{sc} = \frac{\pi}{4} \times 40^2 \times x$

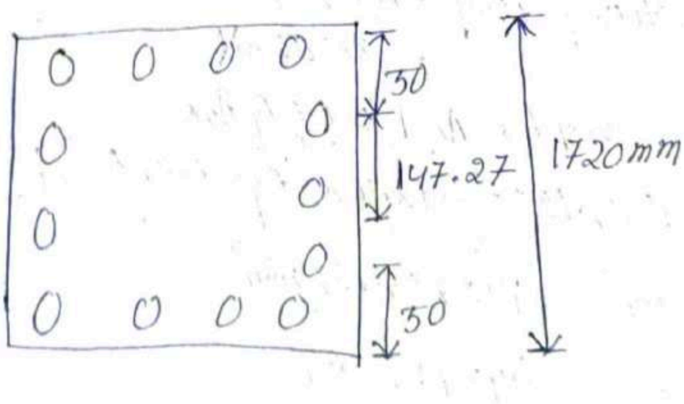
$\Rightarrow 29584 = \frac{\pi}{4} \times 40^2 \times x$

$\Rightarrow x = 24$ nos.

spacing $= \frac{D - 2d'}{11}$

$= \frac{1720 - 2 \times 30}{11}$

$= 147.27\ mm$



Design a circula[r] ... cement to carry ... with the detail o[f] ...

Given data :-

$P_u = 2000 kN$

factored load - ...

$A_{sc} = 0.01 A_g$

Assume,

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

$f_y = 415 N/mm^2$

$P_u = 0.4 F_{ck} A_c + 0.$...

$\Rightarrow 3000 \times 10^3 = 0.4 \times$ ...

$\Rightarrow A_g = 280360$

$A_g = \frac{\pi}{4} D^2$

$\Rightarrow 280360.73 = \frac{\pi}{4}$ ...

$\Rightarrow D = 597.46 mm$

$\simeq 600mm$

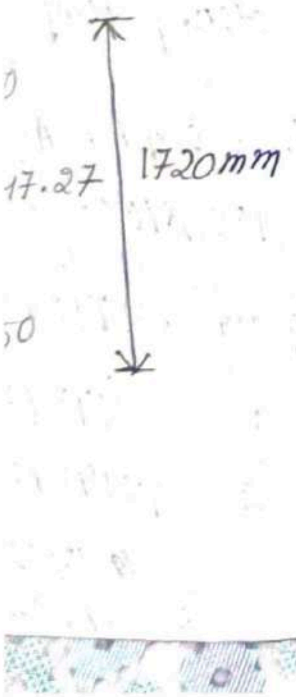
A_g Provided $= \frac{\pi}{4}$ ...

$= \frac{\pi}{4}$ ...

$=$

$A_{sc} = 0.01 A_g$

$= 0.01 \times$ ...



Design a circular column with spiral reinforcement to carry a service load of 2000kN with the detail diagram.

Given data :-

$P_u = 2000\,kN$

Factored load - $1.5 \times 2000 = 3000\,kN$

$A_{sc} = 0.01 A_g$

Assume.

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

$f_y = 415\,N/mm^2$

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

$\Rightarrow 3000 \times 10^3 = 0.4 \times 20 \times (A_g - 0.01A_g) + 0.67 \times 415 \times 0.01A_g$

$\Rightarrow A_g = 280360.73\,mm^2$

$A_g = \frac{\pi}{4} D^2$

$\Rightarrow 280360.73 = \frac{\pi}{4} \times D^2$

$\Rightarrow D = 597.46\,mm$

$\simeq 600\,mm$

A_g Provided $= \frac{\pi}{4} \times D^2$

$= \frac{\pi}{4} \times 600^2$

$= 282743.33\,mm^2$

$A_{sc} = 0.01 A_g$

$= 0.01 \times 282743.33 = 2827.43\,mm^2$

Assume $\phi = 16mm$

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

$\Rightarrow 2827.43 = \frac{\pi}{4} \times 16^2 \times x$

$\Rightarrow x = 15$ nos.

$P_u = 1.05\,(0.4 f_{ck} A_c + 0.67 f_y A_{sc})$

$\Rightarrow 3000 \times 10^3 = 1.05\,(0.4 \times 20 \times (282743.33 - A_{sc})$
$+ 0.67 \times 415 \times A_{sc}$

$\Rightarrow A_{sc} = 2204.02 mm^2$

check :-

$\frac{A_{sc}}{A_g} = \frac{2204.02}{282743.33} = 0.007 \leq 1\%$ (o

$A_{sc} = \frac{\pi}{4} \times \phi^2 \times x$

$\Rightarrow 2204.02 = \frac{\pi}{4} \times 16^2 \times x$

$\Rightarrow x = 11$ nos.

$D_c = D - 2c_c$

$= 600 - 2 \times 40$

$= 520mm$

Pitch $= \frac{1}{6} \times D_c$

$= \frac{1}{6} \times 520$

$= 86.66mm$

Pitch-

$\frac{V_{sp}}{V_c} \geq 0.36\,(\frac{A_g}{A_c}$

$V_{sp} = \frac{\pi\,(D_c - \phi_{sp})}{\frac{\pi}{4} \times D_c^2 \times}$

$\Rightarrow \frac{\pi\,(D_c - \phi_{sp})\,A_{sp}}{\frac{\pi}{4} \times D_c^2 \times P}$

Assume

$\phi_{sp} = 8mm$

$A_{sp} = \frac{\pi}{4} \times \phi_{sp}$

$= \frac{\pi}{4} \times 8$

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

$\Rightarrow \frac{\pi\,(520 - 8)\,50}{\frac{\pi}{4} \times (520)^2}$

$\Rightarrow P = 66.21mm$

Pitch-

$$\frac{V_{sp}}{V_c} \geq 0.36\left(\frac{A_g - A_c}{A_c}\right)\frac{f_{ck}}{f_y}$$

$$V_{sp} = \frac{\pi(D_c - \phi_{sp})A_{sp}}{\frac{\pi}{4} \times D_c^2 \times P}$$

$$\Rightarrow \frac{\pi(D_c - \phi_{sp})A_{sp}}{\frac{\pi}{4} \times D_c^2 \times P} \geq 0.36\left(\frac{A_g - A_c}{A_c}\right)\frac{f_{ck}}{f_y}$$

$3.33 - \frac{\cancel{28.27}}{A_x}$

$\leq 1\%$ (ok)

Assume

$\phi_{sp} = 8mm$

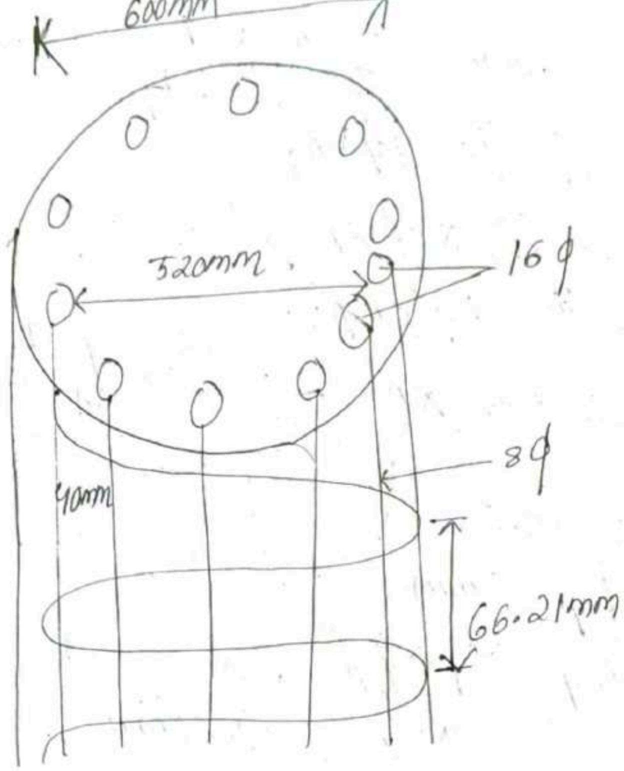
$A_{sp} = \frac{\pi}{4} \times \phi_{sp}^2$

$= \frac{\pi}{4} \times 8^2 = 50.26 mm^2$

$A_g = \frac{\pi}{4} d^2 = \frac{\pi}{4} \times (520)^2 = 212371.66 mm.$

$$\Rightarrow \frac{\pi(520 - 8)50.26}{\frac{\pi}{4} \times (520)^2 \times P} = 0.36\left(\frac{282743.33}{\frac{\pi}{4} \times (520)^2} - 1\right) \times \frac{20}{415}$$

$\Rightarrow P = 66.21 mm < 75 mm$ (Ok)



Problem-2

Design a circular column to carry an axial load of 1500kN using.

(i) Lateral ties

(ii) Helical Reinforcement.

Use M_{25} mix and Fe415 grade of steel.

Given data :-

$P_u = 1500 kN$

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

$f_y = 415 N/mm^2$

Factored load $= 1.5 \times 1500 = 2250 kN$

$P_u = 0.4 f_{ck} A_c + 0.6$

$\Rightarrow 2250 \times 10^3 = 0.4 \times$

$\Rightarrow A_g = 177437.79$

$A_g = \frac{\pi}{4} \times D^2$

$\Rightarrow 177437.79 = \frac{\pi}{4}$

$\Rightarrow D = 475.31mm$

A_g Provided $= \frac{\pi}{4} \times$

$= \frac{\pi}{4}$

$= 19$

$A_{sc} = 0.01 A_g$

$= 0.01 \times 19$

$= 1963.49$

$A_{sc} = \frac{\pi}{4} \times 16$

$\Rightarrow 1963.49 = \frac{\pi}{4}$

$\Rightarrow x = 10$ nos

Pitch :-

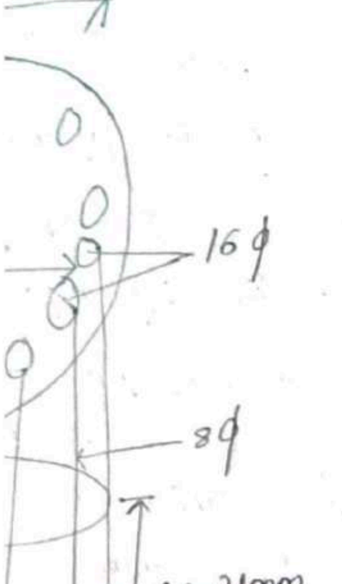
(i) As per codebook

$D = 500mm$

(ii) $16 \times 16 = 256mm$

(iii) $300mm$

Hence pitch = 2



nn to carry an axial

5 grade of steel.

2250 kN

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

$\Rightarrow 2250 \times 10^3 = 0.4 \times 25 \times (A_g - 0.01 A_g) + 0.67 \times 415 \times 0.01 A_g$

$\Rightarrow A_g = 177437.79 mm^2$.

$A_g = \frac{\pi}{4} \times D^2$

$\Rightarrow 177437.79 = \frac{\pi}{4} \times D^2$

$\Rightarrow D = 475.31 mm \simeq 500 mm$

A_g Provided $= \frac{\pi}{4} \times D^2$

$= \frac{\pi}{4} \times (500)^2$

$= 196349.54 mm^2$.

$A_{sc} = 0.01 A_g$

$= 0.01 \times 196349.54$

$= 1963.49 mm^2$

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

$\Rightarrow 1963.49 = \frac{\pi}{4} \times 16^2 \times x$

$\Rightarrow x = 10$ nos.

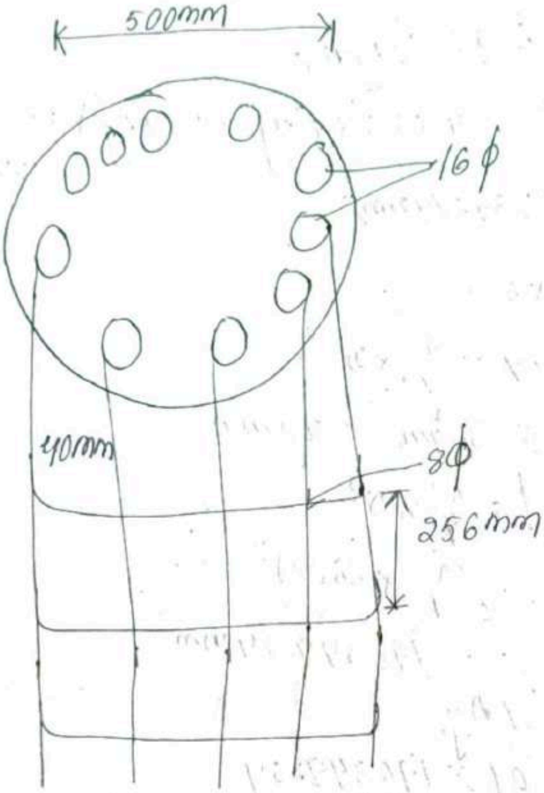
Pitch :-

(i) As per codebook
D = 500mm

(ii) 16X16 = 256mm

(iii) 300mm

Hence Pitch = 256mm c/c



(ii) Helical Reinforcement :-

$P_u = 1.05\,(0.4 f_{ck} A_c + 0.67 f_y A_{sc})$

$\Rightarrow 2250 \times 10^3 = 1.05\,(0.4 \times 25 \times (196349.54 - A_{sc}) + 0.67 \times 415 \times A_{sc})$

$\Rightarrow A_{sc} = 669.13\,mm^2$

check :-

$\frac{A_{sc}}{A_g} = \frac{669.13}{196349.54} = 0.003 < 1\%$ (ok)

$A_{sc} = \frac{\pi}{4} \times \phi^2 \times x$

$\Rightarrow 669.13 = \frac{\pi}{4} \times 1$

$\Rightarrow x = 4$ nos.

$D_c = D - 2 \times$

$= 500 - 2$

$= 420\,m$

Pitch $= \frac{1}{6} \times$

$= \frac{1}{6}$

$= 70\,m$

Pitch.

$\frac{\pi (D_c - \phi_{sp})}{\frac{\pi}{4} \times D_c^2 \times P}$

Assume ϕ_{sp}

$A_{sp} =$

$=$

$=$

$A_g =$

$=$

$=$

$\Rightarrow \frac{\pi (420-8)}{\frac{\pi}{4} \times (420)}$

$\Rightarrow P = 64.86$

16ϕ

ϕ

$56mm$

$.67 f_y A_{sc})$

$(196349.54 - A_{sc})$

$\times (\cancel{A_g - 0.01 A_g})$

$415 \times \cancel{0.01 A_g}\ A_{sc}$

$.003 < 1\%\ (ok)$

$\Rightarrow 669.13 = \frac{\pi}{4} \times 16^2 \times x$

$\Rightarrow x = 4$ nos.

$D_c = D - 2 \times c$

$= 500 - 2 \times 40$

$= 420mm$

$pitch = \frac{1}{6} \times D_c$

$= \frac{1}{6} \times 420$

$= 70mm$

Pitch.

$$\frac{\pi (D_c - \phi_{sp}) A_{sp}}{\frac{\pi}{4} \times D_c^2 \times P} = 0.36 \left(\frac{A_g - A_c}{A_c}\right) \frac{f_{ck}}{f_y}$$

Assume $\phi_{sp} = 8mm$

$A_{sp} = \frac{\pi}{4} \times \phi_{sp}^2$

$= \frac{\pi}{4} \times 8^2$

$= 50.26\ mm^2$

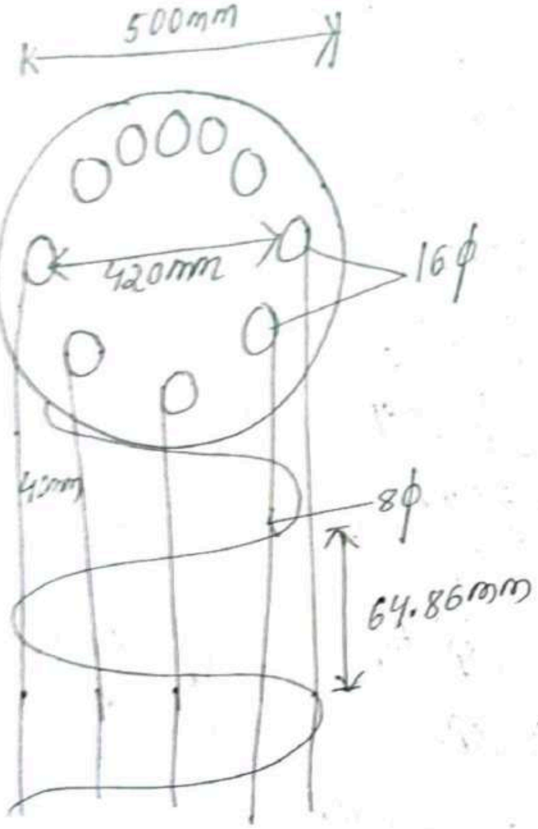
$A_g = \frac{\pi}{4} d^2$

$= \frac{\pi}{4} \times (500)^2$

$= 196349.54\ mm$

$$\Rightarrow \frac{\pi (420 - 8) 50.26}{\frac{\pi}{4} \times (420)^2 \times P} = 0.36 \left(\frac{196349.54 - \frac{\pi}{4}(420)^2}{\frac{\pi}{4}(420)^2}\right) \times \frac{20}{415}$$

$\ldots 06\ mm < 75mm\ (ok)$



Problem-3

A 4m high column is effectively held is position at act both end and restrained again rotation at one end. its diameter is restricted to 40cm. calculate the reinforcement if it is required to carry a factored axial load of 1500 kN use M_{20} mix and Fe415 grade of steel.

Given data

$l = 4m$

$d = 40cm = 400mm$

$P_u = 1500kN$

$f_{ck} = 20 N/mm$

$f_y = 415 N/m$

$l_{eff} = 0.80 \times$

$\frac{l_{eff}}{D} = \frac{3.}{0.4}$

∴ Hence it

unsupported

50

$= \frac{3.2}{500} + $

$= 0.0197 m$

$= 19 mm$

maximum

$e_{max} = 0.0$

$= 0.0$

$= 0.0$

$= 2$

∴ Hence ec

$P_u = 0.4 f_{ck}$

$\Rightarrow 1500 \times 10^3 =$

$\Rightarrow A_{sc} = 183$

$A_g = \frac{\pi}{4} \times d$

$= \frac{\pi}{4} \times$

$= 12566$

$>16\phi$

-8ϕ

64.86mm

...ffectively held in position ...restrained again rotation ...n is restricted to ...forcement if it is required ...ial load of 1500 kN use ...de of steel.

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

$f_y = 415\ N/mm^2$

$l_{eff} = 0.80 \times L = 0.80 \times 4 = 3.2\ m$

$$\frac{l_{eff}}{D} = \frac{3.2}{0.4} = 8 < 12$$

$\therefore$ Hence it is an short column.

$$\frac{\text{unsupported length of column}}{500} + \frac{D}{30}$$

$$= \frac{3.2}{500} + \frac{0.4}{30}$$

$= 0.0197\ m$

$= 19\ mm$

maximum eccentricity

$e_{max} = 0.05 \times B \times D$

$= 0.05 \times 1 \times 0.4$

$= 0.02\ m.$

$= 2\ mm$

$\therefore$ Hence eccentricity $= 19\ mm$

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

$\Rightarrow 1500 \times 10^3 = 0.4 \times 20 \times (A_g - A_{sc}) + 0.67 \times 415 \times A_{sc}$

$\Rightarrow A_{sc} = 1831.84\ mm^2$

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

$= \frac{\pi}{4} \times (400)^2$

$= 125663.7\ mm$

Assume $\phi = 16mm$

$\Rightarrow A_{sc} = \frac{\pi}{4} \times 16^2 \times x$

$\Rightarrow 1831.84 = \frac{\pi}{4} \times 16^2 \times x$

$\Rightarrow x = 10$ nos.

Pitch :-

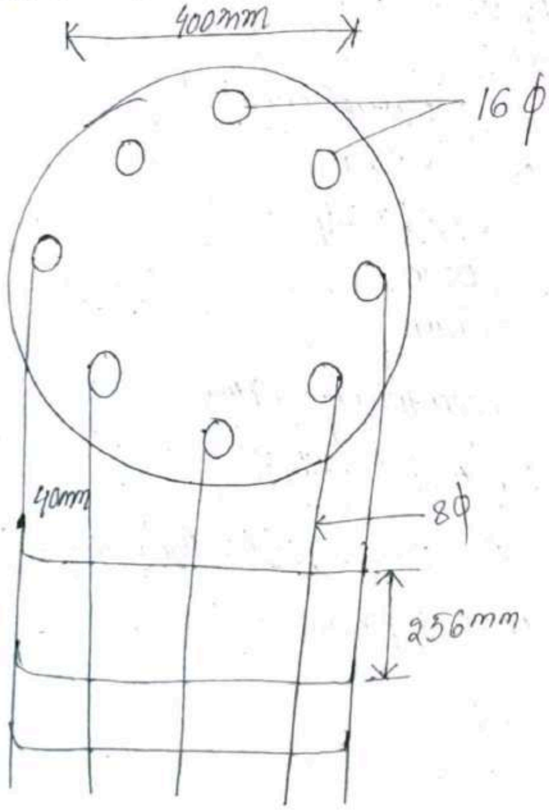
(i) As per code book

$D = 500mm$

(ii) $16 \times 16 = 256mm$

(iii) 300mm

Hence pitch = 256 mm c/c



Problem-4

An axially loade
size the effect
3m it carries
out the reinfo

Given data

$b = 300mm$

$D = 300mm$

$L_{eff} = 3m$

$P_u = 2000kN$

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

$f_y = 415 N/mm$

Factor load = 1.

=

$P_u = 0.4 f_{ck} A_c$

$\Rightarrow 3000 \times 10^3 = 0.4$

$\Rightarrow A_{sc} = 8442.$

Assume $\phi = 16m$

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

$\Rightarrow 8442.88 = \frac{\pi}{4}$

$\Rightarrow x = 42$ nos

spacing = $\frac{D-}{2}$

= $\frac{30}{}$

Problem-4

An axially loaded column is of 300mm X 300mm size the effective length of the column is 3m it carries a axial load of 2000kN find out the reinforcement $f_{ck} = 20 N/mm^2$, $f_y = 415 N/mm^2$

Given data

$b = 300mm$

$D = 300mm$

$L_{eff} = 3m$

$P_u = 2000kN$

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

$f_y = 415 N/mm^2$

Factor load $= 1.5 \times 2000$
$= 3000kN$

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

$\Rightarrow 3000 \times 10^3 = 0.4 \times 20 \times (A_g - A_{sc}) + 0.67 \times 415 \times A_{sc}$

$\Rightarrow A_{sc} = 8442.88 mm^2$

Assume $\phi = 16mm$

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

$\Rightarrow 8442.88 = \frac{\pi}{4} \times 16^2 \times x$

$\Rightarrow x = 42$ nos.

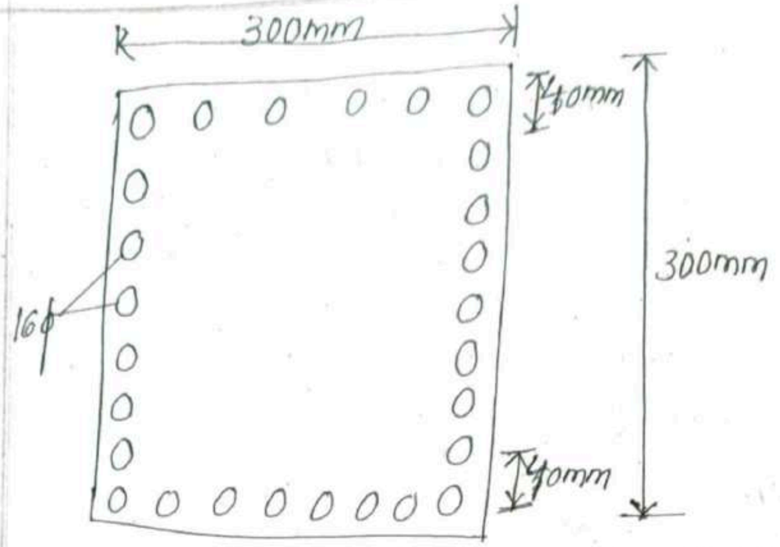
$\text{spacing} = \frac{D - 2 \times d'}{20}$

$= \frac{300 - 2 \times 40}{20} = 11mm$

16 ϕ

-8ϕ

56mm



(Q) Determine the load carrying capacity of a column of size 300X400mm reinforced with 6 rod of 20mm diameter the grade of concrete and steel are M_{20} and fe415 respectively

<u>Given data</u>

$b = 300mm$

$D = 400mm$

$A_{sc} = \frac{\pi}{4} \times 20^2 \times 6 = 1884.95mm^2$

$A_g = 300 \times 400 = 120000mm^2$

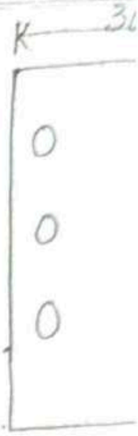
$P_u = 0.4 f_{ck} A_c + 0.67 f_y A_{sc}$

$\Rightarrow P_u = 0.4 \times 20 \times (120000 - 1884.95) + 0.67 \times 415 \times 1884.95$

$\Rightarrow P_u = 1469030.74 N$

$P_u = 1469.03 kN$

$P_u = 979.35 kN.$



<u>Problem-5</u>

Determine
of 980kN on
300X400mm t
M_{20} and Fe
is short.

Given data

$P_u = 980 k$

$b = 300mm$

$D = 400m$

$f_{ck} = 20 N$

$f_y = 415$

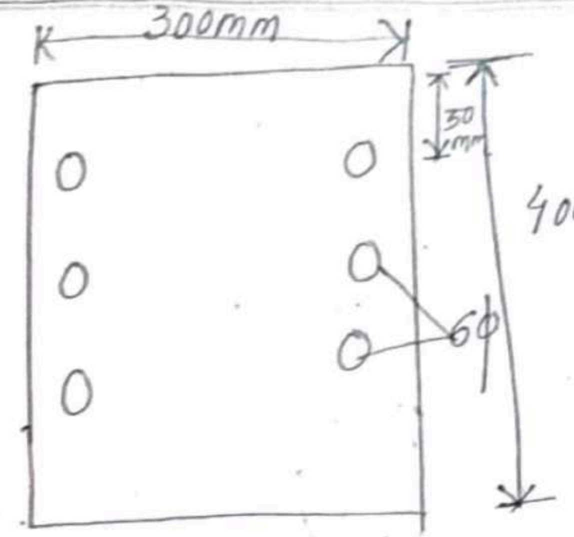
Factored

$= 1.5 \times 98$

$P_u = 0.4 f_c$

$\Rightarrow 1470 \times 10^3 =$

$\Rightarrow A_{sc} = 1$



Problem-5

Determine the steel required to carry a load of 980kN on a rectangular colum of size 300X400mm the grade of concrete and steel are M_{20} and ~~#~~ Fe415 respectively. Assume that the colum is short.

Given data :-

$P_u = 980\,kN$

$b = 300\,mm$

$D = 400\,mm$

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

$f_y = 415\,N/mm^2$

Factored load.

$= 1.5 \times 980 = 1470\,kN$

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

$\Rightarrow 1470 \times 10^3 = 0.4 \times 20 \times (300 \times 400 - A_{sc}) + 0.67 \times 415 \times A_{sc}$

$\Rightarrow A_{sc} = 1888.53\,mm^2$

Assume $\phi = 16mm$

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

$\Rightarrow 1888.53 = \frac{\pi}{4} \times 16^2 \times x$

$\Rightarrow x = 10$ nos.

Pitch:- Spacing

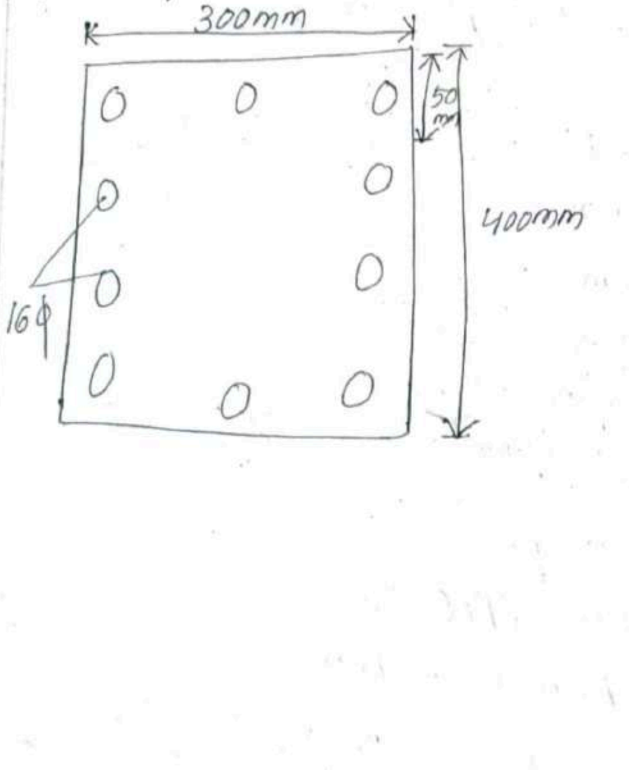
(i) As per code book $D = 500mm$ $\frac{D-2d'}{4} = \frac{400-2\times50}{4}$

$= 75mm$

(ii) $16 \times 16 = 256mm$

(iii) $300mm$

Hence pitch $= 256mm$



Footing

minimum depth

minimum Per

Minimum

minimum

maximum rein

(i) BM consider

(ii) one-way shea

(iii) Two-way shea

Design step

Step-1:-

Load calculat

(i) axial load

where,

self wt. of f

Step-2:-

SBC (Soil Bea

Step-3:-

Find sides of

Step-4:-

Check for soil

$\frac{P}{A}$ = stress

Footing

minimum depth of footing = 150 mm

minimum Percentage of steel :-

minimum reinforcement = 0.12% bD [Fe415, 500]

minimum reinforcement = 0.15% bD [mild steel, Fe250]

maximum reinforcement = 4% of bD

(i) BM consider
(ii) one-way shear
(iii) Two-way shear (Punching failure)

Design step :-

Step-1 :-

Load calculation
(i) axial load + self wt. of the following.

where,
self wt. of footing = 10% of axial load.

Step-2 :-

SBC (Soil Bearing capacity) = $\frac{\text{Total load}}{\text{Area}}$

Step-3 :-

Find sides of the column

Step-4 :-

Check for soil reaction,

$\frac{P}{A}$ = stress < SBC (ok)

step-5 :—

calculation of effective depth

$$M = \frac{\left(\frac{w}{l^2} \times l\right)\left(\frac{l-a-2d}{2}\right)}{2} \text{ (for one way shear)}$$

$$M = \frac{\left(\frac{w}{l^2} \times l\right)\left(\frac{l-a-d}{2}\right)^2}{2} \text{ (for two-way shear)}$$

Find depth from

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

step-6 :—

Find Ast from

$M_u = 0.87 f_y A_{st} d \left(1 - \frac{A_{st} f_y}{b d f_{ck}}\right)$ (Page No-96)

check for, $A_{st\,min}$, $A_{st\,max}$

calculation no. of bars

spacing $= \frac{a \times \frac{\pi}{4} \times \phi^2}{A_{st} \text{ Provided}}$

Find $P_{tlim} = ?$

step-7 :—

check for one-way shear

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

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

$\tau_v \nless \tau_c$ (OK)

check for tw

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

$\tau_v > \tau_c$ (ok

$\tau_c' = k \tau_c$

where

$\boxed{k = 0.5 + \beta_c}$

where

$\beta_c = \frac{\text{Leng}}{\text{Leng}}$

$\tau_c' \ngtr \tau_c$ (

step-8 :—

check for de

find actua

=

step-9 :—

Find the app

$\frac{P_u}{A} = \frac{\text{Fact}}{}$

Now find all

if the actu

check for two-way shear:-

$\tau_v = \frac{V_u}{bd}$, $V_u = \frac{wl}{2}$

$\tau_v > \tau_c$ (ok)

$\tau_c' \ngtr k\tau_c$

where

$$\boxed{k = 0.5 + \beta_c}$$

where

$$\beta_c = \frac{\text{Length of shorter side of column}}{\text{Length of longer side of column}}$$

$\tau_c' \ngtr \tau_c$ (ok)

step-8:-

check for development length:-

find actual length to be provided

$= \frac{L-a}{2} - c_c$

step-9:-

find the applied bearing stress

$\frac{P_u}{A} = \frac{\text{factor load}}{a^2} = \sigma$

Now find allowable bearing stress = $0.45 f_{ck}$

if the actual stress > allowable stress (ok)

Problem-1

Design a square spread footing to carry a column load of 1400kN from a 400mm square column containing 20mm bars as the ties column containing 20mm bars as the longitudinal steel. the bearing capacity of soil at the base of footing 1m below the ground level is 100 kN/m² consider the unit wt. of earth is 20 kN/m³ use $f_{ck} = 25\ N/mm^2$, $f_y = 415\ N/mm^2$ and load factor 1.5.

Given data

$P = 1400\,kN$

$a = 400\,mm$

$SBC = 100\,kN/m^2$

$\gamma = 20\,kN/m^3$

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

$f_y = 415\,N/mm^2$

self. wt. of the footing = 10% of axial load

$= \frac{10}{100} \times 1400 = 140\,kN$

Total load = axial load + self wt. of the footing

$= 1400 + 140$

$= 1540\,kN$

Factored load $= 1.5 \times 1540$

$= 2310\,kN$

$SBC = \frac{\text{Total load}}{\text{Area}}$

$\Rightarrow 100 = \frac{2310}{\text{Area}} \Rightarrow \text{Area} = 23.1\,m^2$

sides of the

$M_u = \frac{\left(\frac{w}{l^2} \times l\right)}{2}$

$= \left[\frac{2310}{(4.8)^2} \times\right.$

$=$

$= 4658.5$

$M_{ulim} = k\,f_{ck}$

$\Rightarrow 4658.5 \times 10^6$

$\Rightarrow d = 592.99$

$\cong 600\,mm$

$2d = 2 \times 600$

$= 1200\,mm$

$M_u = 0.87 f_y A_{st}$

$\Rightarrow 4658.5 \times 10^6 =$

$\Rightarrow A_{st} = 11107.7$

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

$\Rightarrow 1107.78 = \frac{\pi}{4}$

$\Rightarrow x = 36$ no.

Ast Provided

pread footing to carry a
kN from a 400mm square
ing 20mm bars as the
the bearing capacity of soil
r the base of footing 1m
evel the unit wt. of earth
$= 25 \text{ N/mm}^2$, $f_y = 415 \text{ N/mm}^2$
t.

ng = 10% of axial load
40 kN
ad + self wt. of the footing
10
l
X1540
0 kN
–
ea = $23.1 m^2$

sides of the column = $\sqrt{\text{Area}}$
$= \sqrt{23.1}$
$= 4.8 \text{ m}$

$$M_u = \frac{\left(\frac{w}{l^2} \times l\right)(l-a)^2}{2}$$

$$= \frac{\left[\frac{2310}{(4.8)^2} \times 4.8\right](4.8-0.4)^2}{2}$$

$= 4658.5 \text{ kN}$

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

$\Rightarrow 4658.5 \times 10^6 = 0.138 \times 25 \times 4.8 \times d^2$

$\Rightarrow d = 592.99 \text{mm}$
$\cong 600 \text{mm}$

$2d = 2 \times 600$
$= 1200 \text{mm}$

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

$\Rightarrow 4658.5 \times 10^6 = 0.87 \times 415 \times A_{st} \times 1200 \times \left(1 - \frac{A_{st} \times 415}{4800 \times 1200 \times 25}\right)$

$\Rightarrow A_{st} = 11107.78 m^2$

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

$\Rightarrow 1107.78 = \frac{\pi}{4} \times 20^2 \times x$

$\Rightarrow x = 36 \text{ nos}$

A_{st} Provided $= \frac{\pi}{4} \times 20^2 \times 36$
$= 11309.73 \text{mm}^2$

$$\text{spacing} = \frac{1000}{\frac{A_{st}}{\frac{\pi}{4}\phi^2}}$$

$$= \frac{1000}{\frac{11309.73}{\frac{\pi}{4} \times 20^2}} = 27.77 \text{ mm}$$

$$P_{tlim} = 100 \times \frac{A_s}{bd}$$

$$= 100 \times \frac{11309.73}{4800 \times 1200}$$

$$= 0.19\%$$

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

$$= \frac{\left(\frac{w}{l^2} \times l\right)\left(\frac{l-a-2d}{2}\right)}{2}$$

$$= \frac{\left(\frac{2310}{4.8^2} \times 4.8\right)\left(\frac{4.8-0.4-2\times1.2}{2}\right)}{2}$$

$$= 240.625 \text{ kN}$$

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

$$= \frac{240.625 \times 10^3}{4800 \times 1200}$$

$$= 0.04 \text{ mm}$$

$\tau_v < \tau_c$ (ok)

Hence $\tau_c > \tau_v$

check for two

$$\tau_c' = k\tau_c$$

$$k = 0.5 + \beta_c$$

$$k = 0.5 + 1 = 1.5$$

$$\tau_c' = k\tau_c$$

$$\tau_c' = 1 \times 0.28$$

Hence $\tau_c' = \tau_c$ (

Development len

$$L_d = \frac{\phi\, 0.87 f_y}{4\tau_{bd}}$$

$$= \frac{20 \times 0.8}{4 \times 1.}$$

$$= 1289.46 \text{ m}$$

L_d Provided :

=

=

Hence L_d Provide

Load calculation

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

$$= \frac{2310 \times 10}{400 \times 400}$$

27.77 mm

0.48×1.2
2

Hence $\tau_c > \tau_v$ (ok)
check for two way shear

$\tau_c' = k\tau_c$

$k = 0.5 + \beta_c \quad \left(\beta_c = \frac{1}{1} = 1\right)$

$k = 0.5 + 1 = 1.5$

$\tau_c' = k\tau_c$

$\tau_c' = 1 \times 0.28 = 0.28$

Hence $\tau_c' = \tau_c$ (ok)

Development length

$L_d = \frac{\phi\, 0.87 f_y}{4 \tau_{bd}}$

$= \frac{20 \times 0.87 \times 415}{4 \times 1.4}$

$= 1289.46 mm$

L_d Provided $= \frac{L-a}{2} - c_c$

$= \frac{4800 - 400}{2} - 50$

$= 2150 mm$

Hence L_d Provided $> L_d$ (ok)

Load calculation -

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

$= \frac{2310 \times 10^3}{400 \times 400} = 14.43 N/mm^2$

allowable bearing stress $= 0.45 \times f_{ck}$

$= 0.45 \times 25$

$= 11.25\ N/mm^2$

Excess stress $= 14.43 - 11.25$

$= 3.18\ N/mm^2$

Load = stress × Area

$= 3.18 \times 400 \times 400$

$= 508800\ N$

Ast required $= \dfrac{P}{0.67 f_y}$

$= \dfrac{508800}{0.67 \times 415}$

$= 1829.88\ mm^2$

Ast min = 0.5 % of column

$= \dfrac{0.5}{100} \times (400)^2$

$= 800\ mm^2$ (ok)

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

$\Rightarrow 1829.88 = \frac{\pi}{4} \times 16^2 \times x$

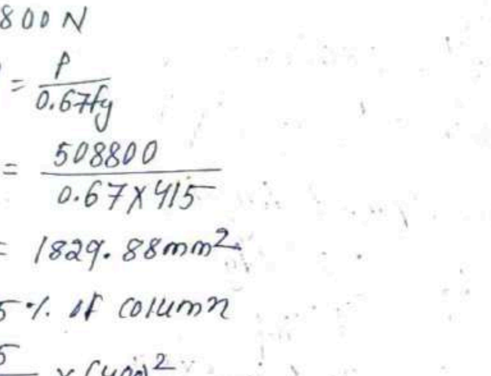
$\Rightarrow x = 10$ nos

Ast required -

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

$= \frac{\pi}{4} \times 16^2 \times 10$

$= 2010.61\ mm^2$



Retaining wall :-

(i) Retaining walls are ... for supporting soil ... can be retained at ... two sides.

(ii) Retaining walls are ... restrain soil to a ... be naturally keep to.

(iii) They are used to boun... different elevations of ... possing undesirable ... land scape needs ... hill side farming of ...

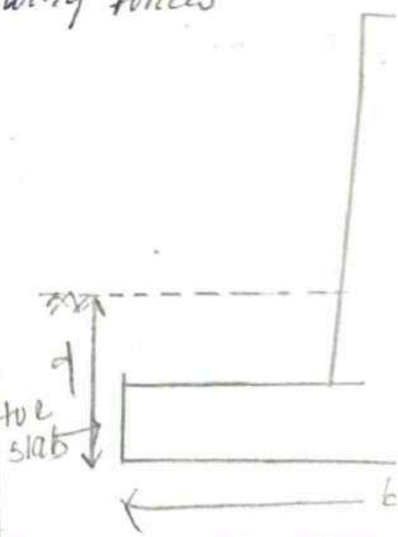
Forces Acting on R...

Lateral earth pressu...

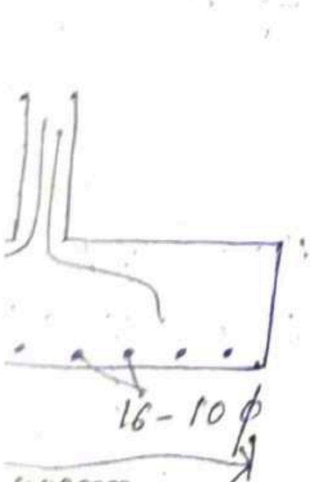
surcharge load

axial load

wind forces



$= 0.45 \times f_{ck}$
$= 0.45 \times 25$
$= 11.25\ N/mm^2$
11.25
mm^2



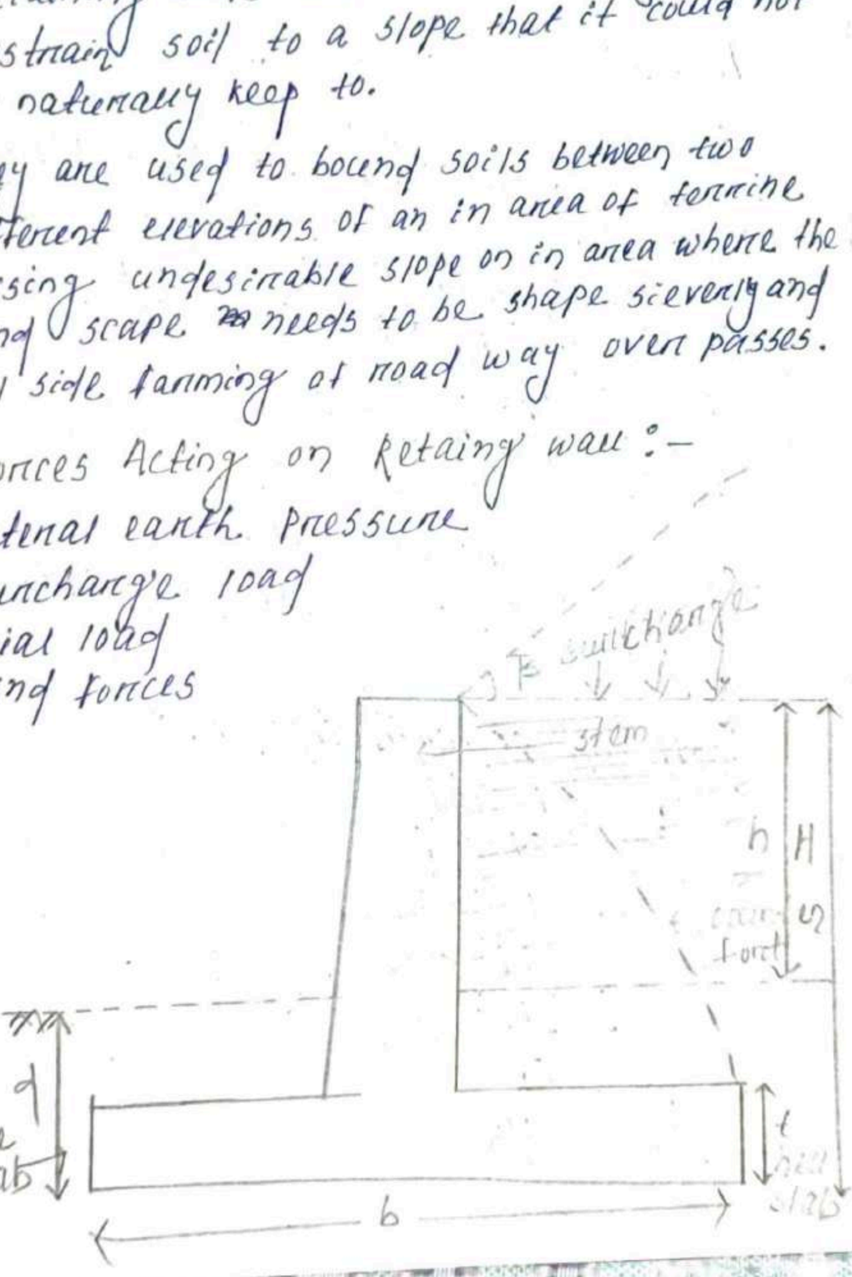
Retaining wall :-

(i) Retaining walls are relatively rigid bars used for supporting soil laterally show that it can be retained at different level on the two sides.

(ii) Retaining walls are structure design to restrain soil to a slope that it could not be naturally keep to.

(iii) They are used to bound soils between two different elevations of an in area of terrine possing undesirable slope on in area where the land scape ~~m~~ needs to be shape sieverly and hill side farming of road way over passes.

Forces Acting on Retaing wall :-
Lateral earth pressure
surcharge load
axial load
wind forces



H = Total height of Retaing wall
h = height of the stem
d = effective depth
b = width of the slab
t = thickness of slab

Problem - 1

Design a cantilever Retaing wall to retain the earth of height 5.5m above lower ground level fix the basic dimention and carry out the stability check of Retaing wall design and detail all the structural component.

SBC = 175 kpa
ϕ = 30° (soil angle)
μ = 0.5
unit weight of soil = 18 kN/m³
use M_{20} and Fe_{415} grade of concrete.

Solⁿ

coefficient of earth pressure :-

$$K_a = \frac{1-\sin\phi}{1+\sin\phi} = \frac{1-\sin 30^\circ}{1+\sin 30^\circ} = \frac{1}{3}$$

$$K_p = \frac{1}{1/3} = 3$$

Preliminary dimenti

$\gamma = 18\,kN/m^3$

SBC, q_0 = 175 kpa

The minimum depth

$$d_{min} = \frac{q_0}{\gamma}\left[\frac{1-}{1+}\right.$$

$$= \frac{175}{18}\left[\right.$$

$$= \frac{175}{162}$$

$= 1.08m \cong$

overall height o

$= 5.5 + 1.2 =$

Base width -

$$b = \sqrt{\frac{3P}{2\gamma}} =$$

$$P = \frac{1}{2}\,ka \times$$

$$= \frac{1}{2} \times \frac{1}{3} \times ($$

$= 134.67\,kN$

~~the~~ the width -

$\frac{1}{3} b = \frac{1}{3} \times 3.3$

Hence provide
base width =

ning wall

)

etaing wall to retain the
above lower ground..
ntion and carry out the
aing wall design and
component.

$18\ kN/m^3$
grade of concrete.

Pressure :-

Preliminary dimentions:-

$\gamma = 18\ kN/m^3$

SBC , $q_0 = 175\ kPa = 175\ kN/m^2$

the minimum depth of foundation is

$$d_{min} = \frac{q_0}{\gamma}\left[\frac{1-\sin\phi}{1+\sin\phi}\right]^2$$

$$= \frac{175}{18}\left[\frac{1-\sin 30^\circ}{1+\sin 30^\circ}\right]^2$$

$$= \frac{175}{162}$$

$$= 1.08m \simeq 1.2m$$

overall height of the wall

$$= 5.5 + 1.2 = 6.7m$$

Base width -

$$b = \sqrt{\frac{3P}{2\gamma}} = \sqrt{\frac{3 \times 134.67}{2 \times 18}} = 3.35m$$

$$P = \frac{1}{2}\ ka \times \gamma \times H^2$$

$$= \frac{1}{2} \times \frac{1}{3} \times (6.7)^2 \times 18$$

$$= 134.67\ kN$$

toe width -

$$\frac{1}{3} b = \frac{1}{3} \times 3.35 = 1.2m$$

Hence provide toe width = 1.2m
base width = 4m

Thickness of slab-

$= \frac{H}{12}$ or $\frac{H}{15}$

$= \frac{6.7}{12}$ or $\frac{6.7}{15}$

$= 0.55$ or 0.44

Hence provide thickness of slab 0.5m.

max^m moment at the base of stem:-

$= \left(\frac{1}{2} \times k_a \times \gamma \times h^2\right) \times \frac{h}{3}$

$= \left[\frac{1}{2} \times \frac{1}{3} \times 18 \times (6.2)^2\right] \times \frac{6.2}{3}$

$= 238.3$ kNm

Factored moment $= 238.3 \times 1.5 = 357.49$ kNm

$M_u = k f_{ck} \times bd^2$

$\Rightarrow 357.48 \times 10^6 = 0.138 \times 20 \times 1000 \times d^2$

$\Rightarrow d = 359.89mm$

Assume $d' = 50mm$

$D = d + d'$

$= \cancel{4}50 + 359.89$

$= 409.mm$

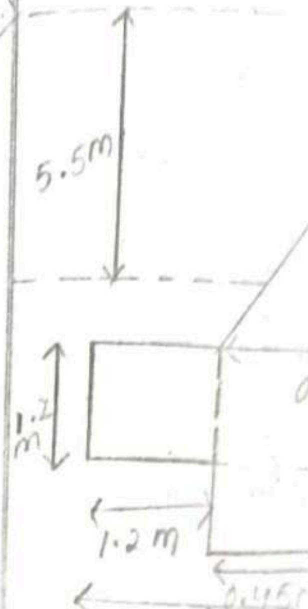
$\cong 450mm$

width of the heel

$= 4 - 1.2 - 0.45$

$= 2.35m$

Hence provide top width of stem = 0.2m



Provide shear ke

Horizontal eart

$= k_a \gamma H$

$= \frac{1}{3} \times 18 \times 6.7$

$= 40.2$ kN.

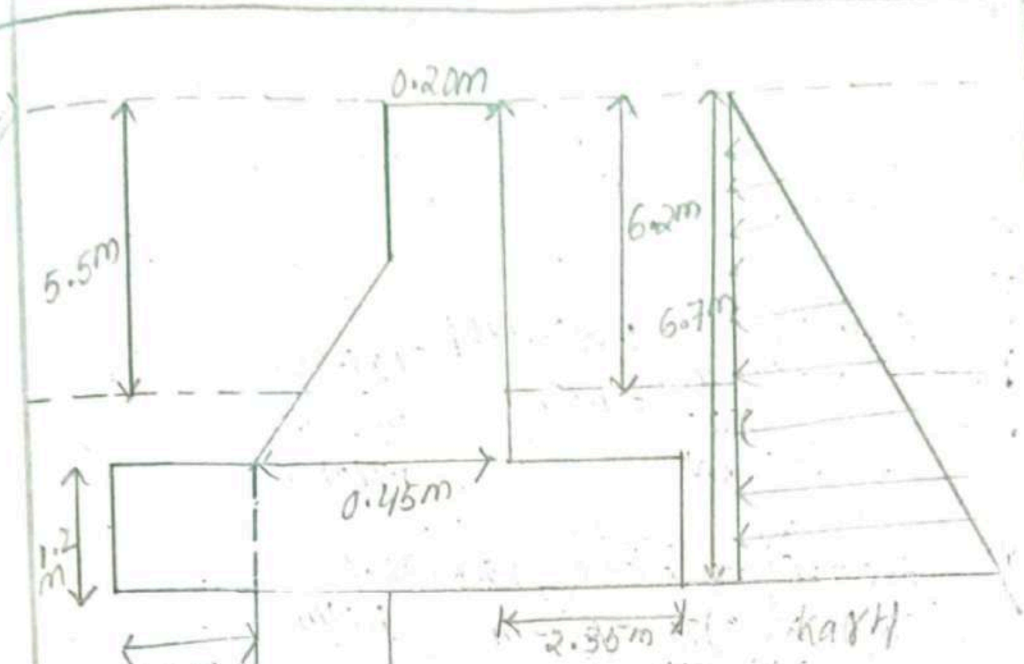
Stability calcu

Horizontal loa

Load type	Horiz loa
Active earth Pressure	$\left(\frac{1}{2} \times\right.$ $= 13$

Sliding force

Overturning



Provide shear key of size (0.45 X 0.5)m.

Horizontal earth pressure

$= k_a \gamma H$

$= \frac{1}{3} \times 18 \times 6.7$

= 40.2 kN.

Stability calculation :-

Horizontal load :-

Load type	Horizontal load (kN)	Perpendicular distance from (A)	Moment about 'A'
Active earth Pressure	$(\frac{1}{2} \times 40.2 \times 6.7)$m = 134.67kN	$\frac{6.7}{3} = 2.23$	2.23X 134.67 = 300.76 kNm

Sliding force = 134.67 kN (←)

Overturning Moment = 300.76 kNm (↻)

Vertical load

Load type	Vertical load (kN)	Perpendicular distance from A (m)	Moment.
Stem (w_1)	$w_1 = (6.2 \times 0.2) \times 25 = 31 kN$	$1.2 + 0.25 + 0.1 = 1.55 m$	$31 \times 1.55 = 48.05$ kNm
Stem (w_2)	$w_2 = (\frac{1}{2} \times 0.25 \times 6.2) 25 = 19.375$ kN	$1.2 + \frac{2}{3} \times 0.25 = 1.37 m$	26.54 kNm
base slab	$w_3 = (4.0 \times 0.5) 25 = \cancel{1}50 kN$	$\frac{4}{2} = 2.0 m$	100 kNm
shear key	$w_4 = (0.45 \times 0.5) 25 = 5.62 kN$	$1.2 + \frac{0.45}{2} = 1.425 m$	8.01 kNm
back fill	$w_5 = (2.35 \times 6.2) \times 18 = 262.26$ kN	$1.2 + 0.45 + \frac{2.35}{2} =$	740.88 kNm
Total	368.26 kN		923.48 kN

$$\boxed{\begin{array}{l} RCC = 25 \\ \text{Plain} = 24 \\ \text{soil} = 18 \end{array}}$$

Total download load = 368.26 kN (↓)
Total moment = 923.48 kNm (↻)
Let, distance of C.G. of vertical loads from of the toe i.e. from point A is $\bar{x}$.

$\Sigma W \cdot \bar{x}$ = Net moment at point 'A'

$\Rightarrow 368.26\bar{x} = 923.48 - 300.76$

$\Rightarrow \bar{x} = 1.69$

$e = \frac{b}{2} - \bar{x}$

$= \frac{4}{2} - 1.69$

$= 0.31$

max^m pressure at A (toe) :-

$P_{max} = \frac{\Sigma W}{b}\left[1 + \frac{6e}{b}\right]$

$= \frac{368.26}{4}\left[1 + \frac{6 \times 0.31}{4}\right]$

$= 134.87\ kN/m^2 <$ SBC (ok)

Min^M pressure at B (heel)

$= \frac{\Sigma W}{b}\left[1 \mp \frac{6e}{b}\right]$

$= \frac{368.26}{4}\left[1 - \frac{6 \times 0.31}{4}\right]$

$= 49.25\ kN/m^2 > 0$ (ok)

Restoring moment = 923.48 kNm
overturning moment = 300.76 kNm

$FS = \frac{RM}{OM} = \frac{M_R}{M_0} = \frac{923.48}{300.76} = 3.07 > 1.55$

$P_p = K\gamma h_1$

$= 3 \times 18 \times 1$

$= 54 \ kN/m^2$

Sliding force $= 134.67 \ kN \ (\leftarow)$

Frinctional force $= \mu . \Sigma w$

$= 0.5 \times 368.26$

$= 184.13 \ kN$

$P = \frac{1}{2} \times P_p \times h_1$

$= \frac{1}{2} \times 54 \times 1$

$= 27 \ kN$

Total restoring force

$= \mu . \Sigma w + P$

$= 0.5 \times 368.26 + 27$

$= 211.13 \ kN/m^2$

$\frac{\text{Restoring force}}{\text{Sliding force}} = 1.56 > 1.55 \ (ok)$