LEARNING MATERIAL

SEMESTER & BRANCH : 4th SEMESTER CIVIL ENGINEERING

THEORY SUBJECT : STRUCTURAL DESIGN – I (TH – 1)

NAME OF THE FACULTY : ER. BABITA SAHU

&

ER. SIDHANTA SEKHAR MAHAR

1st chapter

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R.C.C (Reinforced cement concrete) :-

- It is the mixture of cement coarse aggregate, fine aggregate steel bar & water within proportional limit.
- Reinforced concrete also called reinforced cement concrete.
- A composite materials in which concrete relatively low tensile strength & ductility are compensated by the inclusion of reinforcement having higher tensile strength & ductility.

Objectives of design & detailing

Every structure must be designed to satisfy 3 basic requirement.

(1) Stability :- To prevent overturning, sliding or buckling of the structure or parts of it, under the action of loads.

(2) Strength :- To resist safely the stresses induced by the loads in the various structural members.

(3) Serviceability :- To ensure satisfactory performance under service load condition which implies providing adequate -ns ... deflection crack, width

& vibrations with in acceptable limits & also providing impermeability, durability etc.

Advantages of R.C.C

The following are the major advantages of R.C.C

- Reinforced Concrete has good compressive stress because of concrete.
- RCC also has high tensile stress because of steel.
- It has good resistance to damage by fire & weathering.
- RCC protects steel bars from buckling & twisting at the high temperature.
- RCC prevent steel from rusting.
- RCC is durable.

Disadvantages of RCC :-

(1) The tensile strength of reinforced concrete is about tenth of its compressive strength.

(2) The main steps of using reinforced concrete are mixing, casting & curing All of these affect the final strength.

(3) The cost of forms used for casting is relatively higher.

(4) Shrinkage causes crack development & strength loss.

Different methods of design :-

(1) Working stress method (W.S.M)
(2) Ultimate load method (U.L.M)
(3) Limit state method (L.S.M)

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(1) Working stress method :- (W.S.M)

→ In India, before 1964, most of the structures were designed by working stress method.

→ In working stress method it is assumed that concrete & steel are elastic. At working loads the worst combination of the stresses in materials are not exceeded beyound permissible stresses.

(2) Ultimate load method (U.L.M)

→ The second revision of IS 456 Introduced ultimate load method of design. It gave more economical section than W.S.M

(3) Limit state method (L.S.M)

The third revision of IS 456 Introduced Limit state method of design.

→ Limit state method has become very popular & most of the structures are now designed by limit state method.

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Working stress method

Permissible stress :- In working stress method the stresses in materials are not exceeded beyond their permissible value.

Permissible stress in concrete :-

Grade of concrete	Permissible stress in compression N/mm2 (σ_{cbc})
M20 ⟶	$7\ N/mm^2$
M25 ⟶	$8.5\ N/mm^2$
M30 ⟶	$10\ N/mm^2$

[minimum Grade of concrete = M20]

Grade / Types of steel

(i) Mild steel ⟶ Fe 250

(ii) HYSD steel (High yield strength Deformed bar) ⟶ Fe 415

Grade of steel	(σ_{st}) N/mm²
Fe 250 ⟶	140 N/mm2
Fe 415 ⟶	230 N/mm2
Fe 500 ⟶	$500\ N/mm^2$

	FCK
Fe250 ⟶	$250\ N/mm^2$
Fe 415 ⟶	$415\ N/mm^2$

Modular Ratio (m) :-

It is defind as the ratio of modulus of Elasticity steel to modulus of elasticity of concrete.

i.e. $m = \frac{E_s}{E_c}$ $E_s = 2 \times 10^5 \ N/mm^2$

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

σ_{cbc} = permissible stress in concrete.

1Q find modular ratio of M_{20} grade Concrete ?

Soln Grade of concrete = M20

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

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

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

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V.V.I.P Assumption :-

(1) At any crosssection, plane section before bending remain plane after bending.

(2) All tensile stresses are taken up by reinforcement & none by concrete.

(3) The stress-strain relationship of steel and concrete under working loads is a straight line.

(4) There exist a perfect bond between steel & concrete.

(5) The modular ratio 'm' has the value $\frac{280}{3\sigma_{cbc}}$, where σ_{cbc} = permissible stress in concrete.

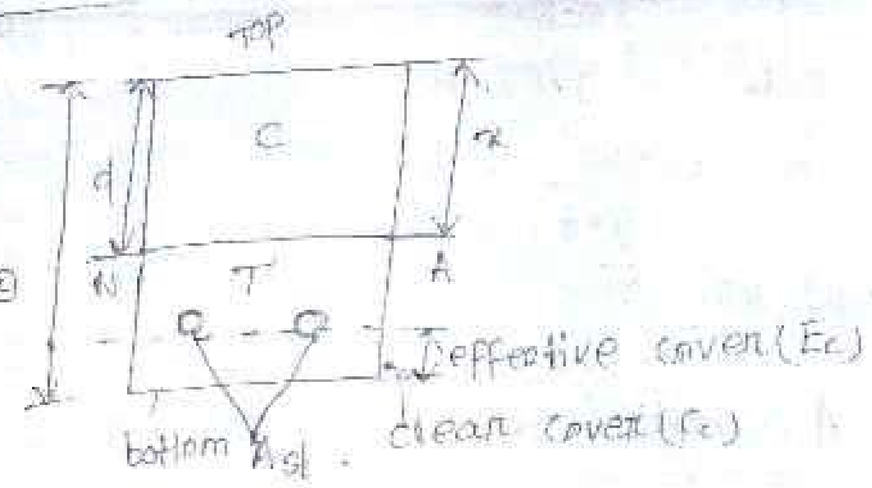
(6) Concrete is assumed to be homogeneous.

Types of beam

(i) singly reinforced beam

(ii) Doubly reinforced beam

singly reinforced beam :-



D = overall depth

It is the distance between top fibre to bottom fibre of beam

effective depth (d)

It is the distance between top fibre of beam to centroid of steel bar.

Effective cover (Ec)

It is distance between centroid of bars to bottom of the beam.

Clear cover (Cc)

It is distance between bottom of bar to bottom of beam.

Types of Section

(i) Balance Section
(ii) under reinforced section
(iii) over reinforced section

(1) Balance reinforced section :-

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

$$\boxed{x = x_{bal}}$$

Area of steel = Area of balance.

(2) under reinforced section :-

> When % of steel in a section is less that required for a balanced section. the section is called under reinforced section.

> In this case concrete stress doesn't reach it's maximum allowable value while the stress in steel reached its maximum permissible

$x_{bal} > x$, $A_{st\,bal} > A_{st}$

over reinforced section :-

when the % of steel in a section is more than that required for a balance section, the section is called over reinforced section.

> In this case the stress in concrete reaches its maximum allowable value earlier than that in steel.

$x_{bal} < x$, $A_{st\,bal} < A_{st}$

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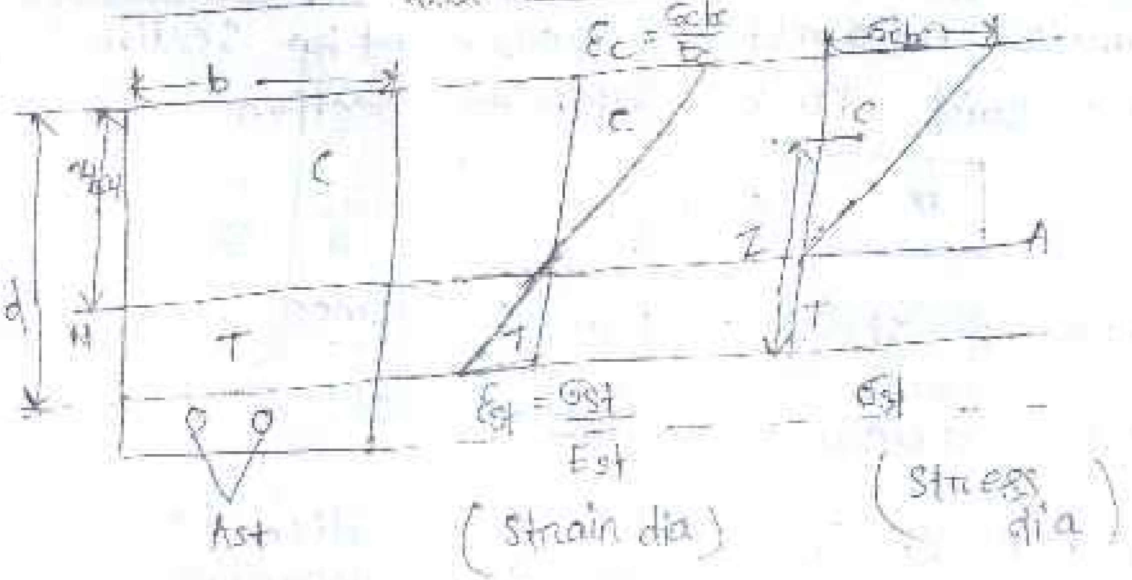
Derivation of formula for balance section :-



$A_{st\,bal}$ = Area of steel in balance section

σ_{cbc} = permissible stress in concrete in compression.

σ_{st} = permissible stress in steel in tension.

E_c = Modulus of elasticity of concrete.

E_{st} = Modulus of elasticity of steel.

z = lever Arm

It is defind as the distance betwen centroid of compression force to centroid of tensile force.

b = width of the beam.

x = N.A depth

To find neutral Axis

From the strain dia $\frac{x_{bal}}{d-x_{bal}} = \frac{\sigma_{cbc}/E_c}{\sigma_{st}/E_{st}}$

$$\Rightarrow \frac{x_{bal}}{d-x_{bal}} = \frac{\sigma_{cbc}}{E_c} \times \frac{E_s}{\sigma_{st}}$$

$$\Rightarrow \frac{x_{bal}}{d-x_{bal}} = \frac{\sigma_{cbc}}{\sigma_{st}} \times \frac{E_s}{E_c}$$

$$\Rightarrow \frac{x_{bal}}{d-x_{bal}} = \frac{\sigma_{cbc} \times m}{\sigma_{st}}$$

$$\Rightarrow \frac{x_{bal}}{d-x_{bal}} = \frac{m\sigma_{cbc}}{\sigma_{st}}$$

$$\Rightarrow x_{bal}(\sigma_{st}) = (d - x_{bal})\, m\sigma_{cbc}$$

$$\Rightarrow x_{bal}(\sigma_{st}) = d\,m\sigma_{cbc} - x_{bal}\, m\sigma_{cbc}$$

$$\Rightarrow x_{bal}\,\sigma_{st} + x_{bal}\, m\sigma_{cbc} = m\sigma_{cbc}\, d$$

$$\Rightarrow x_{bal}(\sigma_{st} + m\sigma_{cbc}) = m\sigma_{cbc}\, d$$

$$\Rightarrow x_{bal} = \frac{m\sigma_{cbc}\, d}{\sigma_{st} + m\sigma_{cbc}}$$

$$\Rightarrow x_{bal} = \left(\frac{\frac{m\sigma_{cbc}}{m\sigma_{cbc}}}{\frac{\sigma_{st}}{m\sigma_{cbc}} + \frac{m\sigma_{cbc}}{m\sigma_{cbc}}} \right) d$$

$$\Rightarrow x_{bal} = d\left(\frac{1}{1 + \frac{\sigma_{st}}{m\sigma_{cbc}}} \right)$$

$$\boxed{x_{bal} = Kd}$$

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

To find out lever Arm (Z)

$$Z = d - \frac{x_{bal}}{3}$$

$$= d - \frac{Kd}{3}$$

$$= d\, 1 - \frac{K}{3}$$

$$= d\, J$$

$$\boxed{Z = dJ}$$

where $\boxed{J = 1 - K/3}$

J - Lever Arm constant
K - Neutral Axis "

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To find total forces :-

C = Total compression

T = Total tension

$C = T$

$C = \sigma cbc \times \frac{1}{2} \times b \times x bal$

$$\boxed{C = \frac{\sigma cbc \times b \times x bal}{2}}$$ force in compression zone

$T = \sigma st \; A st bal$

$$\boxed{T = \sigma st \times Ast bal}$$ force in tension zone.

To find out moment of resistance of the section (MR).

Capacity of a section to resist the moment is known as it's moment of resistance.
MR = Total com. force × LA or total tensile force × LA (which ever is small)
For balanced section C = T so both will have same volume

$MR = (\frac{1}{2} \sigma cbc \times x bal \times b) \times jd$

$= (\frac{1}{2} \times \sigma cbc \times kd \times b) \, jd$

$= (\frac{1}{2} \sigma cbc \times kj) \, bd^2$

$$\boxed{MR = Q bal \times bd^2}$$

where $Q bal = \frac{1}{2} \sigma cbc kj$

Considering tensile forces

FR = total tension × L.A

$$\boxed{MR \text{ or } M_{bal} = \sigma_{st}\, A_{st\,bal}\, jd}$$

To find steel area :-

$$M_{bal} = \sigma_{st}\, A_{st}\, jd$$

$$\Rightarrow \boxed{A_{st\,bal} = \frac{M_{bal}}{\sigma_{st}\, jd}}$$

$P_{t\,bal}$ (percentage of balance)

$$\boxed{P_{t\,bal} = \frac{50k\,\sigma_{cbc}}{\sigma_{st}}}$$

To design balanced section :-

For a given design moment 'M' 'M', M = M_{bal} if w/k of the given or assumed

$$\boxed{d = \frac{M_{bal}}{Q_{bal} \times b}}$$

steel area $A_{st} = A_{st\,bal} = \frac{M}{\sigma_{st}\, jd}$

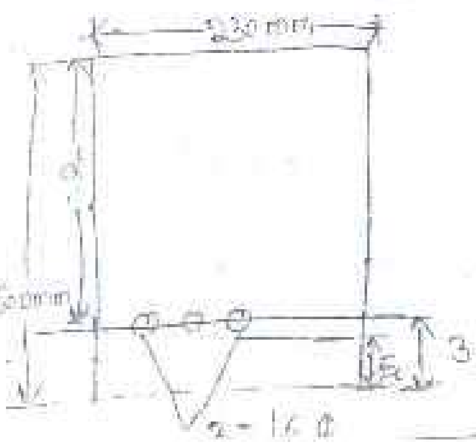
Q6. Determine the effective depth of the beam section

$D = 500$ mm

dia = 16 mm

$d = ?$

$d = D - C_c - \frac{dia}{2}$



$= 500 - 30 - \frac{16}{2}$

$= 500 - 30 - 8 = 462\ mm.$

26 Calculate the design constants for the following mandatee considering the balanced design for singly reinforced section. The materials are grated M20 concrete & mild steel reinforcement.

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Given data :-

For M20 grade concrete $\sigma_{cbc} = 7m$.

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

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

Neutral Axis constant (K)

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

$$= \frac{1}{1 + \frac{140}{13.3 \times 7}} = 0.400$$

Lever arm constant (j)

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

$$= 1 - \frac{0.4}{3} = 0.87$$

MR Constant (Q_{bal})

$Q_{bal} = \frac{1}{2} \times \sigma_{cbc} \times k \times j$

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

$= 1.21$

$(P_t)_{bal} = \frac{50 \sigma_{cbc} k}{\sigma_{st}}$

$= \frac{50 \times 7 \times 0.4}{140} = 1$

Q For a rectangular beam of size 250mm wide × 520mm effective depth, find out the balance depth of N.A, balance lever arm, balanced M.R, balanced steel area, the materials are M20 grade concrete & HYSD reinforcement of grade Fe 415

Given data :-

Width of the beam (b) = 250m.m.

Effective deth(d) = 520 m.m.

For M20 grade concrete $\sigma_{cbc} = 7 N/mm^2$

For Fe 415 grade steel $\sigma_{st} = 230 N/mm^2$

Sol^n (i) To find out Neutral Axis depth (x_{bal})

$x_{bal} = kd$

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

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

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

$= 0.29$

$x_{bal} = kd$

$= 0.29 \times 520 = 150.8\ mm$

(ii) Lever Arm (z)

$Z = dj$

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

$= 1 - \frac{0.29}{3} = 0.9$

$Z = 520 \times 0.9$

$= 468\ mm$

(iii) Moment of Resistance (MR)

$MR = Q_{bal} \times bd^2$

$Q_{bal} = \frac{1}{2} \times \sigma_{cbc} \times k \times j$

$= \frac{1}{2} \times 7 \times 0.29 \times 0.9$

$= 0.91$

$MR = 0.91 \times 250 \times 520^2$

$= 61516\ N \cdot mm$

$= 61.51\ kN \cdot m$

$$\boxed{A_{st\,bal} = \frac{P_{t\,bal} \times bd}{100}}$$

$$P_{t\,bal} = \frac{50\,\sigma_{cbc}\,k}{\sigma_{st}} = \frac{50 \times 7 \times 0.29}{230}$$

$= 0.44$

$$Ast_{bal} = \frac{0.44 \times 250 \times 520}{100}$$

$= 572 mm^2$

Conc grade	steel grade	σbc	σst	K	J	Qbal	Pt bal
M_{20}	Fe 250	7	140	0.4	0.87	9.21	1
M_{20}	Fe 415	7	230	0.29	0.9	0.91	0.44

5. A simply supported rectangular beam of 4m span carries a uniform distributed load of 26 kN/m. The width of the beam is 230mm. Find the depth & steel area for the balanced design. Use M20 grade conc & mild steel reinforcement.

Given data

Span length(l) = 4m

udl = 26 kN/m

$$\text{moment} = \frac{wl^2}{8}$$

$$= \frac{26 \times 4^2}{8} = 52 \text{ kNm}$$

$$d = \sqrt{\frac{M}{Q_{bal} \times b}}$$

$$= \sqrt{\frac{52 \times 10^6}{1.21 \times 230}} = 432.26 \simeq 432.3 \text{ mm}$$

$$\text{steel area } Ast_{bal} = \frac{M}{\sigma_{st} \, j d}$$

$$= \frac{52 \times 10^6}{140 \times 0.87 \times 432.3}$$

$= 987.57\,mm^2$

$\simeq 988\,mm^2$

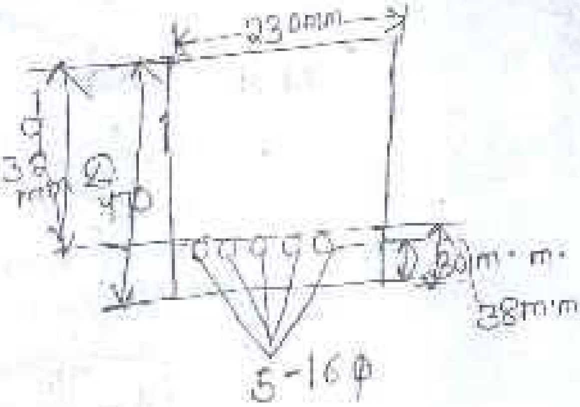
$A_{st} = 988\,mm^2$

Assume 5 no of bar 16m·m dia

$Area = 5 \times \frac{\pi}{4} \times 16^2$

$= 1005\,mm^2$

provide 5no of 16m·m dia bar



Assume $C_c = 30$m·m·

Effective cover

$= \frac{16}{2} + C_c$

$= 8+30 = 38$m·m

overall depth

D = d+ Effective cover

$= 432.3 + 38 = 470.3$ m·m·

D = 470 m·m·

d = 470 - 38 = 432 m·m·

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1.Q For a rectangular beam of size 230 mm wide × 520 m·m effective depth ; Find out the balance depth of n·A ; balance lever arm, balanced , M·R balanced steel area, the materials are M25 Concrete & HYSD reinforcement grade of grade Fe250 .

Given data:-

Width of beam (b) = 250 m.m

Effective depth (d) = 520 m.m

M_{25} grade concrete σ_{bc} = 8.5 N/mm²

Fe 250 grade steel σ_{st} = 140 N/mm²

(i) Neutral Axis balance

x_{bal} = Kd

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

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

$$= \frac{1}{1 + \frac{140}{10.98 \times 8.5}}$$

= 0.39

x_{bal} = 0.39 × 520 = 202.8 m.m.

(ii) Leaver Arm (z) = dj

$$J = 1 - \frac{K}{3} = 1 - \frac{0.39}{3} = 0.87$$

z = 0.87 × 520 = 452.4 m.

= ~~0.8 × 520~~ = ~~416~~ m.

(iii) MR constant (Qbal)

MR = $Q_{bal} \times bd^2$

$= \frac{1}{2} \times 8.5 \times 0.39 \times 0.87$

= 1.44

MR = 1.44 × 250 × 520²

= 97.34 N.mm

= 9734 N/mm

$$Ast\,bal = \frac{Pt\,bal \times bd}{100}$$

$$Pt\,bal = \frac{50\,\sigma_{cbc}\,k}{\sigma_{st}}$$

$$= \frac{50 \times 8.5 \times 0.439}{140} = 1.183$$

$$Ast\,bal = \frac{1.18 \times 250 \times 520}{100}$$

$$= 1534\,mm^2$$

20. A simply supported rectangular beam of 6m span carries a u.d.l of 36 KN/m The width of the beam is 230mm. Find the depth & steel are for the balanced design use M20 grade concrete & mild steel reinforcement.

Ans Given data:-

span length = 6mt

u.d.l = 36 KN/m

width of beam = 230 m.m.

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

$$= \frac{36 \times 6^2}{8} = 162\ KN\,m$$

$$d = \sqrt{\frac{M}{Q_{bal} \times b}} = \sqrt{\frac{162 \times 10^6}{1.21 \times 230}} = 762.95\,m.m.$$

$$= 762.9\ m.m$$

steel area Ast bal $= \dfrac{M}{\sigma_{st} J d}$

$= \dfrac{162 \times 10^6}{140 \times 0.87 \times 762.9}$

$= 1743.41$

Ast bal $= 1743\ mm^2$

Assume 6 no of bar 20 m·m diametre.

Area $= 6 \times \dfrac{\pi}{4} \times 20^2$

$= 1884.9\ mm^2$

Assume C_c = 30 m·m.

Effective cover $= \dfrac{20}{2} + C_c$

$= \dfrac{20}{2} + 30 = 40$ m·m

overall depth (D)

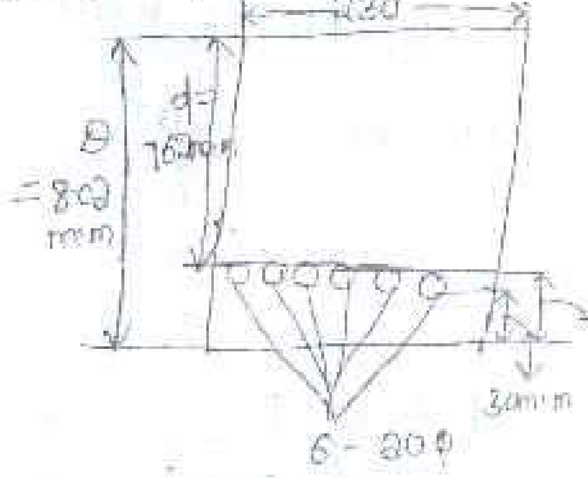
= d + Effective ~~depth~~ cover

$= 762.9 + 40$

$= 802.9$ m·m.

D = 802 m·m.

d = 802 − 40 = 762 m·m.



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% of steel (Pt) $= \frac{100 \, Ast}{bd}$

$= \frac{100 \times 1005}{230 \times 232}$

$= 1.883$

$(Pt)_{bal} = 1$

$Pt_{bal} < Pt$

so, it is O.R.S

Transformed Area method

> A transformed section is a section in which the steel area is replaced by an equivalent concrete area.

> A transformed section consist of a single material, therefore theory of simple bending is applied.

> The transformed area may be steel when concrete is replaced steel or it may be concrete when steel is replaced by concrete.

> Hence a transformed section would mean to a homogeneous concrete section.

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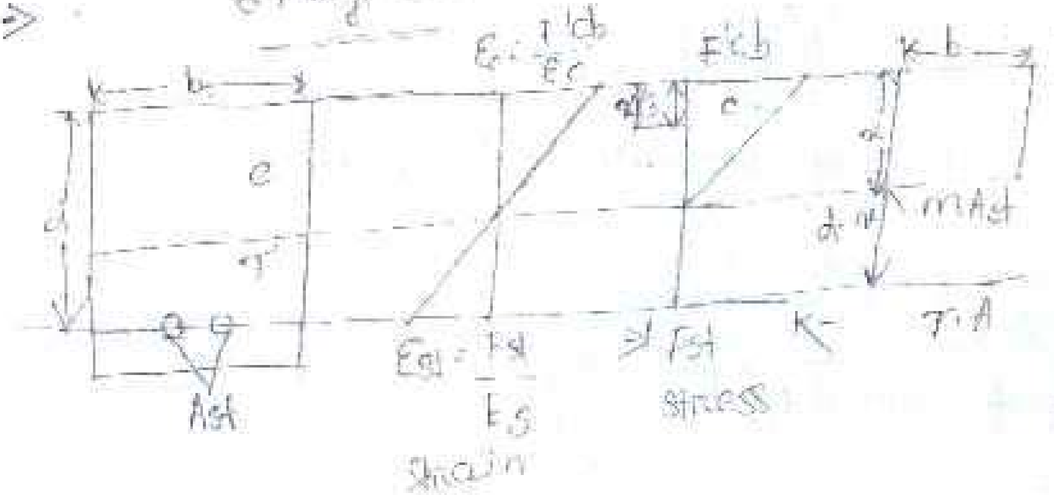
>



Leaver arm

$d - x/3$

$= 460 - \frac{156}{3} = 408$ mm

Stress in steel (f_{st})

$\frac{M}{A_{st} \times (d - x/3)} = \frac{30 \times 10^6}{603 \times 408} = 121.93$ N/mm^2

Stress in concrete (f_{cb})

$\frac{f_{st}}{m} \times \frac{x}{d - x}$

$= \frac{121.93}{13.33} \times \frac{156}{460 - 156}$

$= 4.7$ N/mm^2

Moment of Resistance (Comp)

$M.R = \frac{\sigma_{cbc} \cdot bx}{2} \times L.A$

$= \frac{7 \times 200 \times 156}{2} \times 408 = 44553600$ Nmm $\times 10^{-6}$

$= 44.5$ KNm

M.R in tension

$\sigma_{st}\, A_{st}\, L.A = 140 \times 603 \times 408 = 34443360$ Nmm

$= 34.43$ KNm

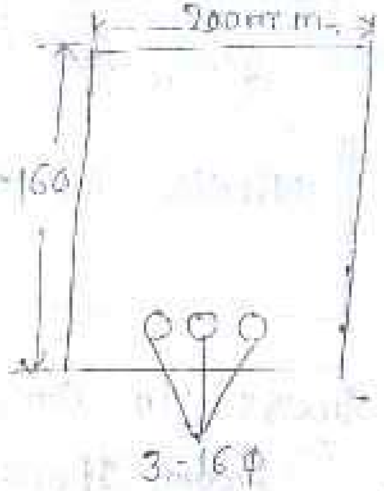
Moment of Resistance of section $= 34.43$ KNm (The smaller of the above two value) have 3no of 16m·m ϕ bar.

Given data :-

width of beam (b) = 200m·m

effective depth = 460m·m.

Moment = 30 kNm



For M_{20} grade Concrete σ_{cbc}

$= 7 N/mm^2$

For Fe250 grade steel σ_{st} = 140 N/mm^2

No of bar = 3

dia of bar = 16m·m.

$A_{st} = 3 \times \frac{\pi}{4} \times 16^2 = 603 \, mm^2$

Modular ratio $= \frac{280}{3 \times 7} = 13.33 \, N/mm^2$

To find out N.A depth (x)

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

$\Rightarrow 200 \times \frac{x^2}{2} = 13.33 \times 603 \, (460-x)$

$\Rightarrow 100x^2 = 13.33 \times 603 \, (460-x)$

$\Rightarrow 100x^2 = 8037 \, (460-x)$

$\Rightarrow 100x^2 = 8037 \times 460 - 8037x$

$\Rightarrow 100x^2 = 3697020 - 8037x$

$\Rightarrow 100x^2 + 8037x - 3697020 = 0$

$\Rightarrow x = 156 \, m \cdot m$

25) A rectangular beam 200mm wide & 460mm effective depth having 3no of 16mm dia bar. The materials are M20 grade concrete & mild steel check whether the sec is balanced design, UR design, O.R.D.

Sol

Given data:-

Width of beam = 200mm

effective depth = 460mm

$A_{st} = 3\times\frac{\pi}{4}\times 16^2 = \cancel{408\,mm^2}\; 603mm^2$

$m = \frac{280}{3\sigma_{cbc}} = \frac{280}{3\times 7} = 13.33\ N/mm^2$

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

$\sigma_{st} = 140N/mm^2$

To find out N.A depth(x)

$bx\cdot\frac{x}{2} = mA_{st}(d-x)$

$200\frac{x^2}{2} = 13.33\times 603\,(460-x)$

$\Rightarrow x = 156mm$

To find balanced design N.A

$x_{bal} = kd = 0.4\times 460 = 184\,mm$

$x_{bal} = 184mm,\quad x = 156mm$

$x_{bal} > x$

$\therefore$ the section is under reinforce section.

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Types of problem

In single reinforced beam, there are two types of problem.

(1) Analysis of the section

(2) Design of the section

Analysis of the section :-

Type -1

To find out the depth of neutral axis for a given section & specifying the type of beam.

Step-1.

(i) If the section & actual stresses in the materials are given, find out the depth of neutral axis using the equation $\boxed{N.A = b \cdot x \cdot \frac{x}{2} = m A_{st} (d-x)}$

(ii) $\boxed{x_{critical} = kd}$, $K = \frac{1}{1+\frac{\sigma_{st}}{m \sigma_{cbc}}}$

(iii) If $x_{actual} < x_{critical}$, then the beam is under reinforce section.

(iv) If $x_{actual} = x_{critical}$; balance section

(v)

Type-2

To find the MR of the given section.

Step-1

(i) Find the depth of N.A.

(ii) Find the depth of critical N.A $x = kd$.

(iii) If $x_{act} < x_{critical}$, the secⁿ is under reinforce section.

$$\boxed{MR = A_{st}\,\sigma_{st}\,(d - x/3)}$$

(iv) If $x_{actual} > x_{critical}$, the section is over reinforce section

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

Type-3

For the given moment & section of beam to check th stresses.

Q. Determine the position of neutral axis of a reinforced concrete beam 250 mm wide & 400 mm effective depth if the stress developed in concrete & steel are 6.3 N/mm² & 212 N/mm² respectively & the materials are M20 grade concrete & HYSD reinforcement of grade Fe415. Also state the type of beam. Assume 4 no. of 16 mm dia bar used.

$\underline{\underline{sol^n}}$ Given data:-

Width of the beam = 230 m·m

Effective depth of beam (d) = 450 m·m

no of bar = 4, dia = 16 m·m

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

$= 804 \cdot 24 \; mm^2$

$m = \frac{280}{3\sigma cbc} = \frac{280}{3 \times 7} = 13 \cdot 33$

For M20 grade concrete $\sigma cbc = 7 \; N/mm^2$

For HYSD bar Fe415, $\sigma st = 230 \; N/mm^2$

step-1

To find out depth of neutral axis (x_{actual})

$bx \cdot \frac{x}{2} = mAst \; (d-x)$

$\Rightarrow 230 \cdot \frac{x^2}{2} = 13 \cdot 33 \times 804 \cdot 24 \; (460 - x)$

$\Rightarrow 115 x^2 = 10720 \cdot 51 \; (460 - x)$

$\Rightarrow 115 x^2 = 4931438 \cdot 6 - 10720 \cdot 5 x$

$\Rightarrow 115 x^2 + 10720 \cdot 51 x - 4931438 \cdot 6 = 0$

$\Rightarrow x = 165 \cdot 49$ m·m

$x_{act} = 165 \cdot 5$ mm

step-2

Critical N·A depth

$x_{critical} = Kd$

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

$= 0.29$

$x_{critical} = 0.29 \times 460$

$= 133.4 \text{ mm}$

$x_{act} = 165.5 \text{ mm}$

$x_{critical} = 133.4 \text{ mm}$

$x_{critical} < x_{actual}$

So the beam is over reinforced section.

step-3

M.R of the section

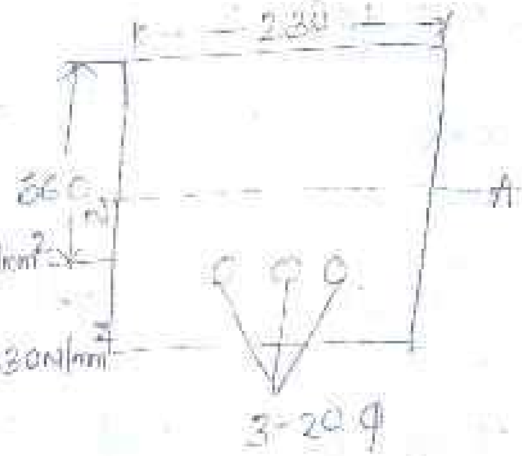
$$MR = \frac{1}{2} \sigma_{cbc} \cdot b \cdot x \times (d - x/3)$$

$$= \frac{1}{2} \times 7 \times 230 \times 165.5 \left(460 - \frac{165.5}{3}\right)$$

$= 61284594.83 \text{ Nmm}$

$= 61.28 \text{ kNm}$

Q. Find the MR of the beam as shown in figure. Also state whether the beam is UR or OR. The materials used M20 grade concrete & HYSD reinforcement.



Given data :-

Materials used M_{20} grade concrete $\sigma_{cbc} = 7 \text{N/mm}^2$

HYSD bar Fe415 $\sigma_{st} = 230 \text{N/mm}^2$

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

$= 942.47$

Neutral depth axis (x_{actual})

$bx \cdot \frac{x}{2} = mAst(d-x)$

$230 \cdot \frac{x^2}{2} = 13.33 \times 942.47 \cdot (560-x)$

$\Rightarrow 115x^2 = 12563.12(560-x)$

$\Rightarrow 115x^2 = 7035347.2 - 12563.12x$

$\Rightarrow 115x^2 + 12563.12x - 7035347.2 = 0$

$\Rightarrow x_{actual} = 198.67$

$Kd = 0.29 \times 560 = 162.4$

$x_{act} = 198.6$ m.m

$x_{critical} = 162.4$ mm

$x_{critical} < x_{actual}$

So the beam is over-reinforced section.

Moment of Resistance

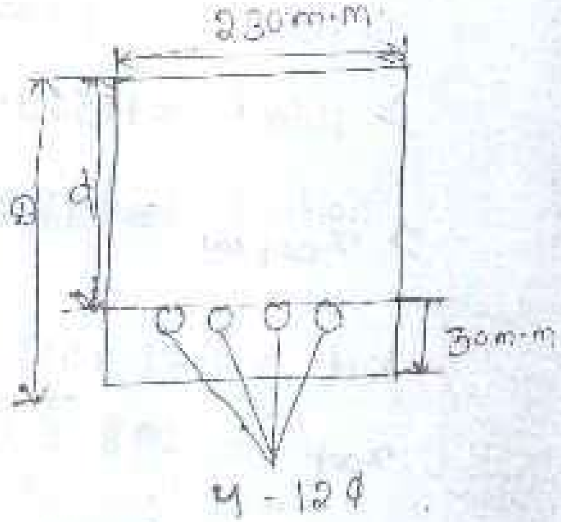
$= \frac{1}{2}\sigma cbc \cdot b \cdot x\,(d-x/3)$

$= \frac{1}{2} \times 7 \times 230 \times 198.6\,(560 - \frac{198.6}{3})$

$= \cancel{89528813.8}$ N/mm 7894528.7 N/mm

$= 78.94$ KN

Q. A simply supported beam of size 230 m.m × 600 m.m overall depth is reinforced with 4 no of 12 m.m dia bar. Find the safe udl on the beam in addition to its self wt on a span of 4m. The materials are M_{20} grade concrete & HYSD reinforcement of Fe 415.



Given data :-

overall depth (D) = 600 m.m

width of beam (b) = 230 mm

no of bar = 4 , dia = 12 m.m

Area of steel (A_{st})

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

$= 452.38\ mm^2$

M_{20} grade conc. $\sigma_{cbc} = 7\ N/mm^2$

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

Neutral axis depth

Assume cc = 30 m.m

$d = 600 - 30 - 6 = 564\ m.m$

neutral axis depth x_{actual}

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

$\Rightarrow 230 \frac{x^2}{2} = 13.33 \times 452 (564 - x)$

$\Rightarrow 115 x^2 = 6025.16 (564 - x)$

$\Rightarrow 115 x^2 = 3398190.24 - 6025.16 x$

$\Rightarrow 115 x^2 + 6025.16 x - 3398190.24 = 0$

$\Rightarrow x_{act} = 147.7$

Critical depth of N.A ($x_{critical}$)

$x_{critical} = K \times d$

$= 0.29 \times 564$

$= 153.56\,mm$

$x_{act} < x_{critical}$, so the beam is under reinforced section.

Moment of Resistance

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

$\Rightarrow MR = 452 \times 230$

$= 53.51\,kNm$

Let the load on beam $= w\,kN/m$

$m = \frac{wl^2}{8} = \frac{w \times 4^2}{8}$

$= \frac{w \times 4^2}{8} \times 53.51$

$w = \frac{53.51 \cdot 8}{4^2} = 26.76\,kN/m$

Self wt of the beam $= 0.23 \times 0.6 \times 25$

$= 3.45\,kN/m$

Safe u.d.l $= 26.7 - 3.45 = 23.25$

25) A simply supported beam over a span of 4·5m. is reinforced with tension reinforcement only. The beam is 250mm wide and has an effective depth of 610mm. It is reinforced with 4 no 20mm dia bars. calculate the stresses in both the materials at the centre of the span when the beam carries a uniformly distributed load of 30 kN/m inclusive of self weight the materials are M20 grade concrete and HYSD reinforcement of grade Fe415.

Sol Given data :-

Width of beam (b) = 250m.m

effective depth (d) = 610m.m.

4 no of bar dia 20m.m.

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

$= 1256.6 \, mm^2$

M20 grade concrete $\sigma cbc = 7 N/mm^2$

HYSD reinforcement $\sigma st = 230 N/mm^2$

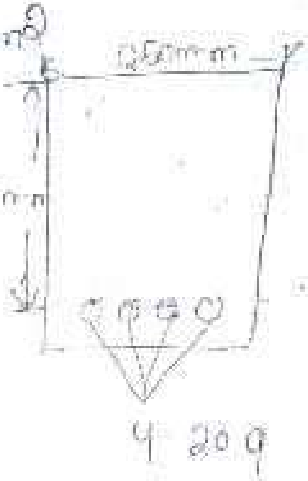
modular ratio :-

$(m) \frac{280}{3\sigma cbc} = \frac{280}{3 \times 7}$

$= 13.33$

moment (M) $= \frac{wl^2}{8} = \frac{30 \times 4.5^2}{8}$

$= 75.93 \, kNm$



Step-1
Neutral axis depth (x)

$bx \cdot \frac{x}{2} = mAst \, (d - x)$

$\Rightarrow 250 \frac{x^2}{2} = 13.33 \times 1256 \, (610 - x)$

$\Rightarrow 125x^2 = 16742.48 \, (610 - x)$

$\Rightarrow 125x^2 = 10212912.8 - 16742.48x$

$\Rightarrow 125x^2 + 16742.48x - 10212912.8 = 0$

$x_{ed} = 226.6$

~~critical~~ ~~neutral~~ ~~axis~~ depth (~~critical~~)

~~$x_{critical} = Kd$~~

~~$= 0.29 \times 610$~~

Step - 2

stress in steel $F_{st} = \dfrac{M}{A_{st}(d - x/3)}$

$$= \frac{73.93 \times 10^6}{1256\left(610 - \frac{226.6}{3}\right)} = 113.11 \text{ N/mm}^2$$

Stress in concrete (F_{cb})

$$\frac{F_{st}}{M} \times \frac{x}{d-x} = \frac{113.11}{13.33} \times \frac{226.6}{610 - 226.6}$$

$= 5.01 \text{ N/mm}^2$

13 May 2021

Q. A rectangular beam 230mm wide × 560mm effective depth is reinforced with 3no of 16mm dia bars calculate the stress in both the materials when a bending moment of 50 kNm is applied The materials are M20 grade concrete & HYSD reinforcement ALSO calculate MR of the section.

Sol^n Given data
Width of beam = 230 m.m.
effective depth (d) = 560 m.m.

$Ast = 3 \times \frac{\pi}{4} \times 16^2 = 603.18 \, mm^2$

M20 grade concrete $\sigma_{cbc} = 7 N/mm^2$

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

$M = 50 KNm$

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

step - 1

To find out N.A depth (x)

$b \cdot x \cdot \frac{x}{2} = m Ast (d - x)$

$\cancel{230} \cdot \frac{x^2}{\cancel{2}} = 13.33 \times 603.18 \, (560 - x)$ (115)

$\Rightarrow 115 x^2 = 13.33 \times 603.18 \, (560 - x)$

$\Rightarrow 115 x^2 = 8037.99 \, (560 - x)$

$\Rightarrow 115 x^2 = 4501274.4 - 8037.99 = 0$

$\Rightarrow 115 x^2 + 8037.99 x - 4501274.4 = 0$

$\Rightarrow x = 165.9$

step - 2

Stress in steel (fst) $= \frac{M}{Ast \, (d - x/3)}$

$= \frac{50 \times 10^6}{603.18 \times (560 - \frac{165.9}{3})}$

$= 164.2 \, N/mm^2$

Stresss in concrete (f_{cb}) $= \frac{F_{st}}{m} \times \frac{x}{d-x}$

$$= \frac{164.29}{13.33} \times \frac{165.95}{560-165.95}$$

$$= 5.19 \ N/mm^2$$

x critical

$x = kd$

$= 0.29 \times 560 = 162.4$ mm

~~165~~ $x_{act} > x_{critical}$

$\therefore$ The beam is over reinforced section.

So, $MR = \frac{\sigma_{cbc} \cdot b x}{2} \times d - \frac{x}{3}$

$$= \frac{7 \times 230 \times 165}{2} \times 560 - \frac{165}{3}$$

$$= 67.43 \text{ KNm}$$

A simply supported beam of 6m span carries a u.d.l of 12KN/m inclusive of self wt. The beam 230 mm wide & the effective depth is 580mm. Find the steel area, the materials are M20 grade conc. & HYSD reinforcement.

Given data:-

width of beam = 230 mm

Effective depth (d) = 580 m.m

u.d.l = 12 KN/m

span length (L) = 6m

M_{20} grade concrete σ_{cbc} = 7 N/mm^2

HYSD reinforcement σ_{st} = 230 N/mm^2

step-1

$$M = \frac{wl^2}{8} = \frac{12 \times 6^2}{8} = 54 \text{ KNm}$$

$$\text{depth req}^d = \sqrt{\frac{M}{R_{bal} \times b}}$$

$$\sqrt{\frac{54 \times 10^6}{0.91 \times 230}} = 507 \text{ mm}$$

Actual depth = 580 m.m

depth req^d = 507 m.m

580 > 507

The beam is under reinforce section.

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

$$= 230 \times A_{st} \, (580 - x/3)$$

$$M = MR$$

$$\Rightarrow 54 \times 10^6 = 230 A_{st} \, (580 - x/3)$$

$$\Rightarrow \frac{54 \times 10^6}{230} = A_{st}(580 - x/3)$$

$$\Rightarrow 234782.60 = A_{st} \, (580 - x/3) \text{ ------- } (1)$$

step - 2

To find depth of N.A

$b x \cdot \frac{x}{2} = m Ast (d - x)$

$\Rightarrow 230 \frac{x^2}{2} = 13.33 \, Ast \, (580 - x)$

$\Rightarrow 115x^2 = 13.33 \, Ast \, (580 - x)$

$\Rightarrow \frac{115x^2}{13.33} = Ast \, (580 - x)$

$\Rightarrow Ast = \frac{8.627}{580 - x}$ ------ (ii)

substituting in eqn (i)

$234782.60 = Ast \times \left(580 - \frac{x}{3}\right)$

$\Rightarrow 234782.60 = Ast \left(\frac{1740 - x}{3}\right)$

$\Rightarrow 234782.60 = \left(\frac{8.627x^2}{580 - x}\right) \times \left(\frac{1740 - x}{3}\right)$

$\Rightarrow 234782.60 = \left(\frac{8.627x^2}{580 - x}\right) \times \left(\frac{1740 - x}{3}\right)$

17 may 2021

(or)

$mR = \sigma st \, Ast \, (d - x/3)$

$54 \times 10^6 = 230 \times Ast \, (d - x/3)$

$\Rightarrow 54 \times 10^6 = 230 \, Ast \, \left(\frac{3d - x}{3}\right)$

$\Rightarrow 54 \times 10^6 = 76.66 \, Ast \, (3d - x)$

$\Rightarrow \frac{54 \times 10^6}{76.66} = Ast \, (3d - x)$

$= Ast \, (3d - x)$ ------ (i)

$= 8.627$

Depth of N.A (x)

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

$230 \frac{x^2}{2} = 13.33 A_{st} (d-x)$

$\Rightarrow \frac{115x^2}{13.33} = A_{st} (d-x)$

$\Rightarrow 8.63 x^2 = A_{st} (d-x)$

$\Rightarrow A_{st} = \frac{8.63 x^2}{d-x}$ ——— (ii)

Substituting in eqn (1)

$\Rightarrow 704409.07 = A_{st} (3d-x)$

$\Rightarrow 704409.07 = \frac{8.63x^2}{d-x} \times (3d-x)$

$\Rightarrow 704409.07 = \frac{8.63x^2}{580-x} \times (3 \times 580 - x)$

$\Rightarrow 704409.07 = \frac{8.63x^2}{580-x} \times (1740 - x)$

$704409.07 \times (580-x) = (8.63x^2)(1740x)$

$\Rightarrow 408557260.6 - 704409.07x = 15016.2x^2 - 8.63x^3$

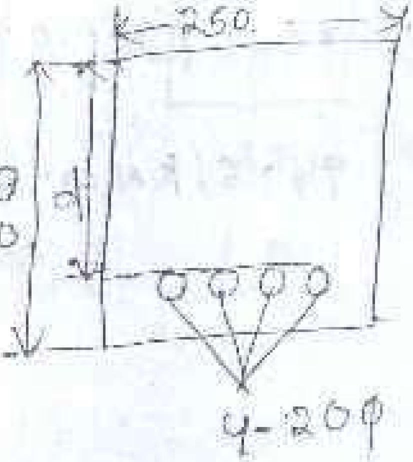
$\Rightarrow 8.63x^3 - 15016.2x^2 - 704409.07x + 408557260.6 = 0$

$\Rightarrow x = 149$ mm

$A_{st} = \frac{8.63x^2}{d-x} = \frac{8.63 \times 149^2}{580 - 149} = 444.52 \text{ mm}^2$

Q A simply supported beam 250mm width & 610 overall depth is reinforced with 4no of 20m.m dia bar. Find out the depth of N.A & state what type of secⁿ. Also determine the M.R.

Given data:-



width of beam(b) = 250 m.m

overall depth(D) = 610 m.m.

$d = d -$ effective cover

$= 610 - 40 = 570$ mm.

4 no of 20m.m. dia bar

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

$= 1256 \text{ mm}^2$

M_{20} grade $\sigma_{cbc} = 7 \text{ N/mm}^2$

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

To find out N.A (x_{actual})

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

$\Rightarrow 250 \frac{x^2}{2} = 13.33 \times 1256 (570 - x)$

$\Rightarrow 125x^2 = 16742.48 (570 - x)$

$\Rightarrow 125x^2 = 9543213.6 - 16742.48x$

$\Rightarrow 125x^2 + 16742.48x - 9543213.6$

$\Rightarrow x_{act} = 217.33$

$x_{critical} = Kd$

$= 0.29 \times 217.33 = 165.3$

$\sim x_{c}$

So it is over-reinforced section.

Moment of Resistance

$\frac{1}{2}\sigma cbc \cdot b \cdot x\left(d-\frac{x}{3}\right)$

$\Rightarrow \frac{1}{2}\times 7\times 250\times 217\cdot 33\times\left(570-\frac{217\cdot 33}{3}\right)$

$\Rightarrow 94617241\cdot 57$ N/mm

$\Rightarrow 94\cdot 61$ KNm. Ans

18 May 2021

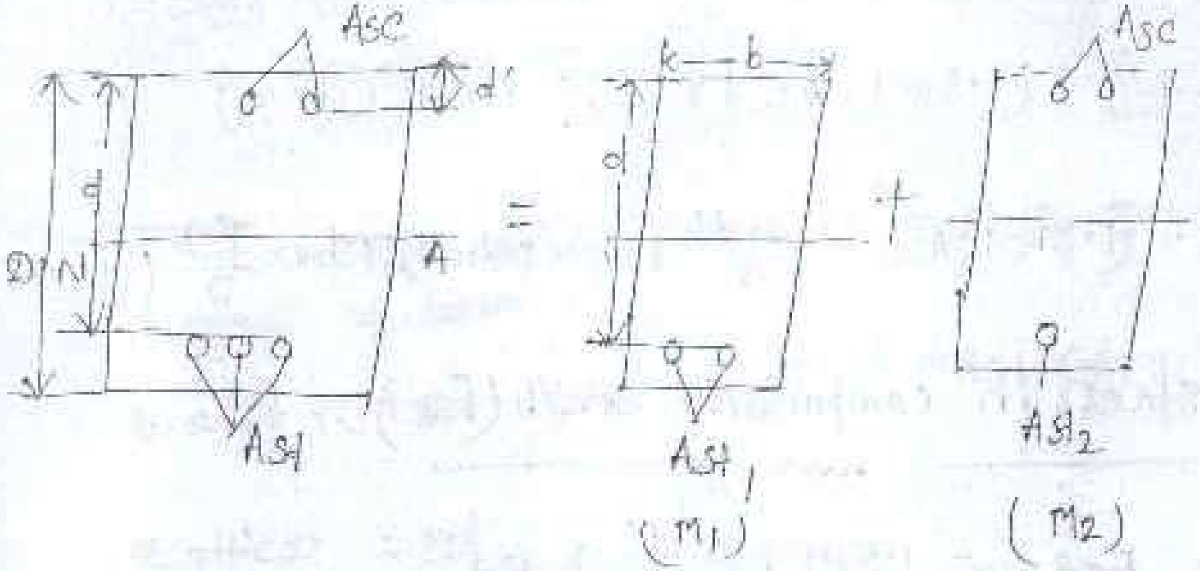
Doubly reinforced beam :-

> For a design moment M, If the size of the rectangular beam section is fixed & the moment of resistance of a singly reinforced section is less than M.

> There are two methods to design such beams.

(i) Increase the concrete mix to increase the capacity of the section.

(ii) Reinforcement are provided in compression zone to give additional strength to the concrete in compression, such beams are called Doubly reinforced beam.



$$\boxed{(\text{Moment})\,M = M_1 + M_2}$$

$$\boxed{M_2 = (1.5\underbrace{m}_{\text{modular ratio}} - 1)\, A_{sc}\, \sigma_{cbc} \left(\frac{x - d'}{x}\right) \times (d - d')}$$

$$\boxed{A_{st} = A_{st_1} + A_{st_2}}$$

$$\boxed{A_{sc} = \frac{M_2}{(1.5m - 1)\sigma_{cbc}\left(\frac{x - d'}{x}\right)(d - d')}}$$

$$\boxed{A_{st_2} = \frac{M_2}{\sigma_{st}(d - d')}}$$

$$\boxed{A_{st_1} = \frac{M_1}{\sigma_{st}\, jd}}$$

* To find out depth of N.A

$$b \cdot x \frac{x}{2} + (1.5m-1) A_{sc} (x-d') = m A_{st} (d-x)$$

$$M = (1.5m-1) A_{sc} \times \frac{x-d'}{x} f_{cb} \times (d-d') + b x \times \frac{f_{cb}}{2} (d - x/3)$$

* Stress in compression steel (f_{sc})

$$F_{sc} = 1.5m \left(\frac{x-d'}{x}\right) f_{cb}$$

* Stress in tensile steel (f_{st})

$$F_{st} = m f_{cb} \left(\frac{d-x}{x}\right)$$

* Find moment of inertia section

$$I_x = \frac{1}{3} b x^3 + (1.5m-1) \times A_{sc} (x-d')^2 + m A_{st} (d-x^2)^2$$

Stress in concrete (f_{cb}) $= \dfrac{M \cdot x}{I_x}$

$$F_{sc} = 1.5m \times \frac{M(x-d')}{I_x}$$

$$F_{st} = m \times \frac{M(d-x)}{I_x}$$

19 may 2021

Types of problems

Type -1

To find out the depth of N·A 'x' specify type of beam.

$b \cdot x \cdot \frac{x}{2} + (1.5m - 1) Asc (x - d') = mAst (d - x)$

$x_{critical} = Kd$

(a) If $x_{actual} < x_{critical}$, then the beam is under reinforced section.

(b) If $x_{act} > x_{critical}$, then the beam is over reinforced section.

Type - 2

For given moment & section of beam to check the stresses.

Type -3

To find out the moment of resistance of the section.

(a) $x_{act} > x_{critical}$, over reinforcement

$M \cdot R = M_1 + M_2$

$= \frac{1}{2} \sigma cbc\, b \cdot x (d - x/3) + (1.5m - 1) Asc\, \sigma cbc \times \left(\frac{x - d'}{x}\right)(d - d')$

(b) If $x_{act} < x_{critical}$, under reinforcement

$\boxed{M \cdot R = Ast\, \sigma st\, (d - \frac{x}{3})}$

$$\bar{y} = \frac{C_1 y_1 + C_2 + y_2}{C_1 + C_2}$$

$y_2 = d'$

$C_1 = \frac{bx}{2} fcb \;,\; y_1 = x/3$

$C_2 = (1.5m-1) Asc \left(\frac{x-d'}{x}\right) fcb$

OR

M.R (compression)

$$\frac{\sigma cbc \times I x}{x}$$

M.R (tension)

$$\frac{\sigma st \times I x}{m(d-x)}$$

Type - 4 : To design the section

(a) Find $M_1 = Qbd^2$

(b) If $M > M_1$; design as doubly reinforced beam.

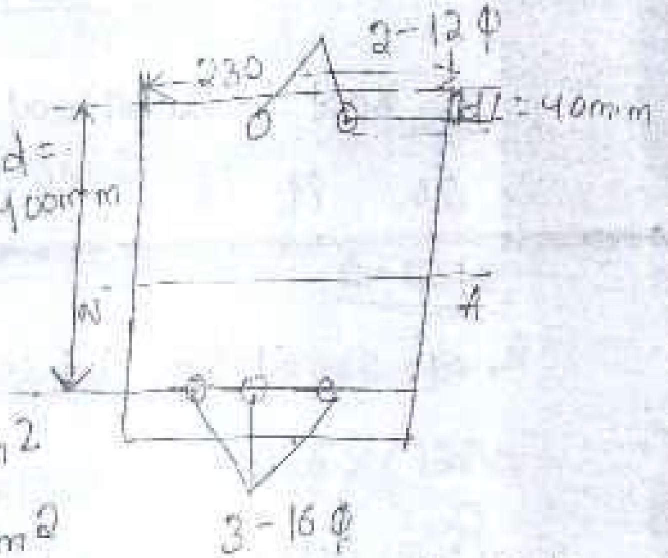
(c) Find $Ast_1 = \frac{M_1}{\sigma st\, jd}$, $Ast_2 = \frac{M_2}{\sigma st (d-d')}$

$$\boxed{Ast = Ast_1 + Ast_2}$$

$$Asc = \frac{M_2}{(1.5m-1)\sigma cbc\left(\frac{x-d'}{x}\right)(d-d')}$$

Depth of N·A, type of beam, stress, MR

16. A rectangular beam is reinforced as shown in fig. find out the maximum stress in concrete & steel If it is subjected to a moment 40 kNm. The materials are M20 grade concrete & HYSD reinforcement. Also find out MR of the section.



Given data:-

width of beam(b) = 230 m·m.

Effective depth(d) = 400 m·m

$d' = 40$ m·m.

$Asc = 2 \times \frac{\pi}{4} \times 12^2 = 226 \text{ mm}^2$

$Ast = 3 \times \frac{\pi}{4} \times 16^2 = 603 \text{ mm}^2$

For M20 grade concrete $\sigma cbc = 7 \text{ N/mm}^2$

HYSD steel $\sigma st = 230 \text{ N/mm}^2$

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

Step 1

To find out depth of N·A

$b \cdot x \frac{x}{2} + (1.5m-1) Asc (x-d') = mAst (d-x)$

$230 \frac{x^2}{2} + (1.5 \times 13.33 - 1) 226 (x-40) = 13.33 \times 603 (400 - x)$

$\Rightarrow 115x^2 + 4292.87\,x(x-40) = 8037.99\,(400-x)$

$\Rightarrow 115x^2 + 4292.87x - 171714.8 = 3215196 - 8037.99x$

$\Rightarrow 115x^2 + 4292.87x + 8037.99x - 171714.8 + 3215196 = 0$

$\Rightarrow 115x^2 + 12330.86x - 3386910.8 = 0$

$x = 126.18$ m.m

$x_{critical} = Kd$

$K = 0.29$

$= 0.29 \times 400 = 116$ m.m.

$x_{act} > x_{critical}$

so it is over reinforced section.

step-2

$$M = (1.5m-1)\,Asc\left(\frac{x-d'}{x}\right) fcb\,(d-d') + bx \times \frac{fcb}{2}\left(d-\frac{x}{3}\right)$$

$$42\times10^6 = (1.5\times13.33-1)\,226\left(\frac{126.18-40}{126.18}\right) fcb\,(400-40) + 230\times126.18\times\frac{fcb}{2}\left(400-\frac{126.18}{3}\right)$$

$\Rightarrow 42\times10^6 = 2931.99 \times 360\,fcb + 29021.4\times\frac{fcb}{2}\times 357.94$

$\Rightarrow 42\times10^6 = 1055516.4\,fcb + 5193954.95$

$\Rightarrow 42\times10^6 = 6249476.35\,fcb$

$$F_{cb} = \frac{42\times10^6}{6249476.35} = 6.72\ N/mm^2$$

Stress in steel in compression

$$F_{sc} = 1.5m\left(\frac{x-d'}{x}\right)F_{cb}$$

$$= 1.5\times13.33\left(\frac{126.18-40}{126.18}\right)\times6.72$$

$$= 91.77\ N/mm^2$$

Stress in steel in tension

$$F_{st} = m.F_{cb}\left(\frac{d-x}{x}\right)$$

$$= 13.33\times6.72\times\left(\frac{400-126.18}{126.18}\right)$$

$$F_{st} = 194.39\ N/mm^2$$

(or)

$$I_x = \frac{1}{3}bx^3 + (1.5m-1)A_{sc}(x-d')^2 + mA_{st}(d-x)^2$$

$$= \frac{1}{3}\times230\times126.18^3 + (1.5\times13.33-1)\times226\times(126.18-40)^2$$

$$+ 13.33\times603(400-126.18)^2$$

$$= 788571009\ N/mm^2$$

$$F_{cb} = \frac{M\cdot x}{I_x} = \frac{42\times10^6\times126.18}{788571009} = 6.72\ N/mm^2$$

$$F_{sc} = 1.5m\times\frac{M(x-d')}{I_x} = \frac{1.5\times13.3\times40\times10^6(126.18-40)}{788571009}$$

$$= 91.8\ N/mm^2$$

$$F_{st} = m \times \frac{M(d-x)}{I_x}$$

$$= \frac{13.33 \times 40 \times 10^6 (400 - 126.18)}{188571009}$$

$$= ~~1\ldots~~$$

$$194 \, N/mm^2$$

Step-3

$$M.R = M_1 + M_2$$

$$= \frac{1}{2} \sigma_{cbc} \cdot b \cdot x (d - x/3) + (1.5m - 1) A_{sc} \sigma_{cbc} \left(\frac{x-d'}{x}\right)(d-d')$$

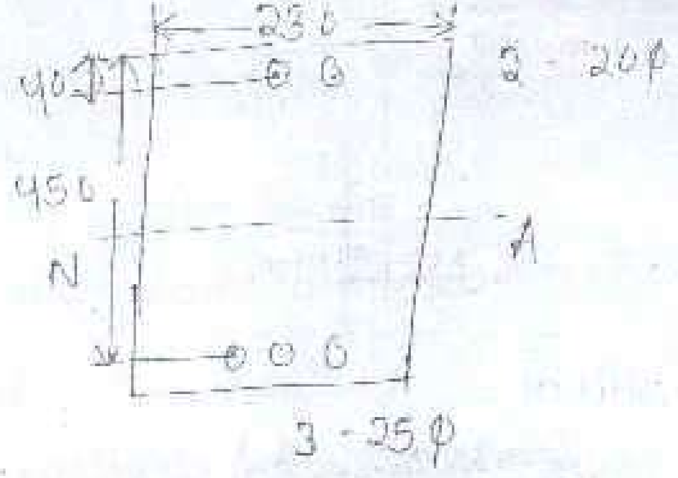
$$= \frac{1}{2} \times 7 \times 230 \times 126.18 \times \left(400 - \frac{126.18}{3}\right) + (1.5 \times 13.33 - 1) 226 \times 7 \times \frac{126.18 - 40}{126.18} (400 - 40)$$

$$= 43746355.24 \, Nmm$$

$$= 43.74 \, KNm$$

21 May 2021

28 A rectangular beam is reinforced as shown in fig. Find out the M.R of the section. The materials are M20 grade concrete & HYSD reinforcement of grade Fe415.



Given data :-

width of the beam = ~~450~~ 230 m.m

$d' = 40$ m.m.

Effective depth = 450 m.m.

$Asc = 2 \times \frac{\pi}{4} \times 20^2 = 628 \ mm^2$

$Ast = 3 \times \frac{\pi}{4} \times 25^2 = 1472 \ mm^2$

For M_{20} grade Conc. $\sigma cbc = 7 N/mm^2$

HYSD steel $\sigma st = 230 N/mm^2$

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

Step-1

To find out N.A

$b \cdot x \frac{x}{2} + (1.5m-1) Asc(x-d') = mAst (d-x)$

$\Rightarrow 230 \frac{x^2}{2} + (1.5 \times 13.33 - 1) \ 628.31 (x-40) = 13.33 \times 1472.62 (450-x)$

$\Rightarrow 115x^2 + 11934.74 (x-40) = 19630.02 (45-x)$

$\Rightarrow 115x^2 + 11934.74x - 477389.6 = 8833509 - 19630.02x$

$\Rightarrow 11x^2 + 31564.76x - 9310898.6 = 0$

$x_1 = 178.67$ m.m

Kd

$0.29 \times 450 = 130.5$ m.m.

$x_{act} > x_{critical}$

so it is over reinforced section.

step - 2

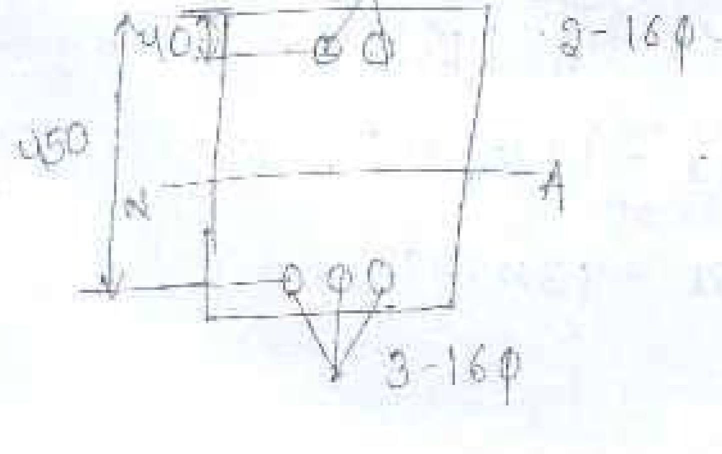
M.R

$$\frac{1}{2} \times 7 \times 230 \times 178.67 \times \left(450 - \frac{178.67}{3}\right) + (1.5 \times 13.33 - 1) \times 628.31 \times 7 \times \left(\frac{178.67 - 40}{178.67}\right)(450 - 40)$$

$= 82741560.76$ Nmm

$= 82.74$ kNm

3Q A rectangular beam is reinforced as shown in fig. Find out the MR of the section. The materials are M_{20} grade conc. & mild steel reinforcement.



22 May 2021

Given data:-

Width of beam (b) = 230 mm.

Effective depth (d) = 450 mm

$d' = 40$ mm.

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

$A_{st} = 3 \times \frac{\pi}{4} \times 16^2 = 603\ mm^2$

M20 grade $\sigma_{cbc} = 7 N/mm^2$

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

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

step-1.

To find out N.A

$b \cdot x \cdot \frac{x}{2} + (1.5m - 1) A_{sc} (x - d') = m A_{st} (d - x)$

$230 \frac{x^2}{2} + (1.5 \times 13.33 - 1)\ 402 (x - 40) = 13.33 \times 603 (450 - x)$

$\Rightarrow 230 \frac{x^2}{2} + (1.5 \times 13.33 - 1)\ 402 (x - 40) = 8037.99 (450 - x)$

$\Rightarrow 115x^2 + 7635.99 (x - 40)$

$\Rightarrow 115x^2 + 7635.99x - 305439.6 = 3617095.5 - 8037.99x$

$\Rightarrow 115x^2 + 15673.98 - 3922535.1 = 0$

$x_{ac} = 128$ mm.

$x_{critical} = kd = 0.9 \times 450 = 180$ mm.

$x_{act} < x_{critical}$ so the beam is in under reinforced section.

$MR = A_{st}\,\sigma_{st} \times (d - \bar{y})$

$C_1 = \frac{bx}{2} f_{cb} = \frac{230 \times 128}{2} f_{cb} = 14720 f_{cb}$

$C_2 = (1.5m - 1) A_{sc} \left(\frac{x - d'}{x} \right) f_{cb}$

$= (1.5 \times 13.33 - 1)\, 402 \left(\frac{128 - 40}{128} \right) f_{cb}$

$= 5249.74\, f_{cb}$

$y_1 = \frac{128}{3} = 42.67$

$y_2 = 40\,m.m.$

$\bar{y} = \frac{C_1 y_1 + C_2 y_2}{C_1 + C_2} = \frac{14720 \cancel{f_{cb}} \times 42.67 + 5249.74 \cancel{f_{cb}} \times 40}{14720 f_{cb} + 5249.74 f_{cb}}$

$= \frac{628102.4 f_{cb} + 209989.6\, f_{cb}}{19969.74\, f_{cb}}$

$\bar{y} = 41.96\,m.m.$

$MR = A_{st}\,\sigma_{st}\,(d - \bar{y})$

$= 603 \times 140\ (450 - 41.96)$

$= 34\ KNm$

OR

$MR\ (comp) = \frac{\sigma_{cbc} \times I_x}{x} = 575011.5176 = 51\ KN$

$MR(tension) = \frac{\sigma_{st}\, I_x}{m(d-x)} = 34\ KN$

24 may 2021

1.

A rectangular cantilever beam of size 230 m.m width × 500 m.m effective depth is subjected to a bending moment of 80 KNm. Design the reinforcement for flexure. The materials are M20 grade concrete & HYSD reinforcement.

Given data:-

width of beam (b) = 230 m.m

Effective depth (d) = 500 m.m.

Bending moment (M) = 80 KNm

M20 grade σcbc = 7 N/m

HYSt reinforcement σst = 230 m.m.

step-1

$M_1 = Q_{bal} \times bd^2$

$= 0.91 \times 230 \times 500^2$

$= 52.33 \text{ KNm}$

$M > M_1$ so the beam is doubly reinforcement.

$Ast_1 = \frac{M_1}{\sigma st\ jd}$

$= \frac{52.33}{230 \times 0.9 \times 500} = 506 \text{ mm}^2$

$M = M_1 + M_2$

$M_2 = M - M_1 = 80 - 52.33 = 27.67 \text{ KNm}$

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

$$A_{sc} = \frac{M_2}{(1.5m-1)\,\sigma_{cbc}\left(\frac{x-d'}{x}\right)(d-d')}$$

$$= \frac{27.67\times10^6}{(1.5\times13.33-1)\,7}$$

$$= 624.73\ mm^2 \simeq 625 mm^2$$

$$A_{st_2} = \frac{M_2}{\sigma_{st}(d-d')} = \frac{27.67\times10^6}{230\,(500-40)}$$

$$= 261.53 \simeq 262 mm^2$$

Assume $d' = 40$ m.m.

$$A_{st} = A_{st_1} + A_{st_2} = 506 + 262 = 768 mm^2$$

$$A_{sc} = 625 mm^2$$

Assume provide 3 no of 20m.m dia bar at top or compression zone.

$$A_{sc} = 3\times\frac{\pi}{4}\times20^2 = 942\ mm^2$$

provide 4 no of 16 mm at bottom of beam

$$A_{st} = 4\times\frac{\pi}{4}\times16^2 = 804\ mm^2.$$

step-2

~~To~~ Find neutral axis depth

$$b\cdot x\cdot\frac{x}{2} + (1.5m-1)\,A_{sc}\,(x-d') = mA_{st}\,(d-x)$$

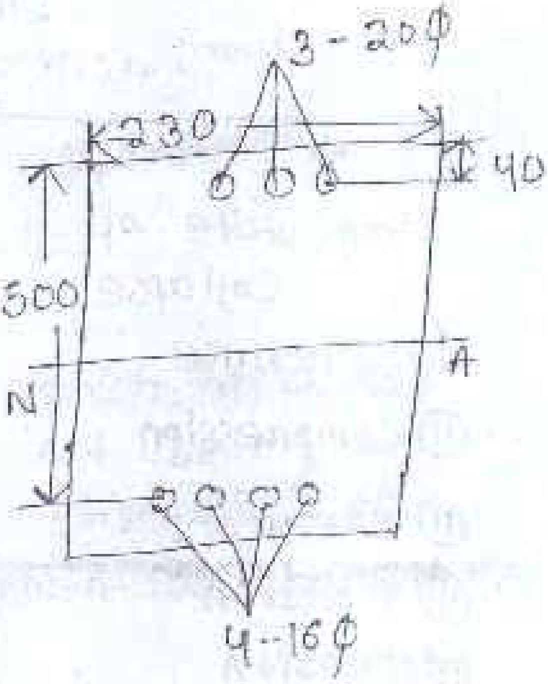
$$= 230\,\frac{x^2}{2} + (1.5\times13.33\times1)\,942\,(x-40) = 13.33\times804\,(500-x)$$

i $\Rightarrow 115x^2 + 17893.29(x-40) = 10717.32(500-x)$

$\Rightarrow 115x^2 + 17893.29x - 715731.6 = 5358660 + 10717.3x$

$\Rightarrow 115x^2 + 28610.61x - 6074391.6$

$\Rightarrow x_1 = 136.93$ mm.



Limit state design 25 May 2021

The acceptable limit for the safety & serviceability requirements before failure occures is called as limit state method.

Limit state

Limit state of collapse
(i) Flexure
(ii) Compression
(ii) shear
(iii) torsion
(iv) Tension

Limit state of serviceability
(1) Durability
(2) stability
(3) fire resistance
(4) Deflection
(5) cracking

Limit ~~state design~~

The accept

characteristic strength of materials

The charecteristic strength of material's is that value of the strength of the material below which not more than 5% of the test results are expected to fail.

Grade of conc.	Charecteristic strength (Fck)
M_{15} ⟶	15 N/mm^2
M_{20} ⟶	20 N/mm^2
M_{25} ⟶	25 N/mm^2

M30 ⟶ 30 N/mm²

M35 ⟶ 35 N/mm²

Grade of steel	characteristic - strength (f_y)
Fe250 ⟶	$f_y = 250\ N/mm^2$
Fe415 ⟶	$f_y = 415\ N/mm^2$
Fe500 ⟶	$f_y = 500\ N/mm^2$

Charecteristic Load

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

31 May 2021

Partial safety factors :-

Types of Load

Dead Load
Live Load
wind Load
Earthquake load
Impact Load
snow Load

Load Combina-tion	Limit state of collapse			Limit state of Serviceability		
	DL	LL	WL	DL	LL	WL
DL + LL	1·5	1·5		1·0	1·0	
DL + WL	1·5		1·5	1·0		1·0
DL+LL+WL	1·2	1·2	1·2	1·0	0·8	0·8

Partial safety factor (γ_m) for materials :-

Materials	partial safety factors
concrete →	1·5
steel →	1·15

Limit state of colapse :- flexure :-

Assumptions

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

→ This assumption means that strain at any point on the cross section is directly proportional to its distance from the neutral axis.

② The maximum strain in concrete at the outermost compression fibre is taken as 0.0035 in bending.

③ The stress - strain diagrame of concrete is parabolic from strain value of zero to 0.002 & corresponding stress value of zero to

The stress now remains constant & strain increase to 0.0035. The relationship between the compressive stress distribution in concrete & the strain in concrete may be assumed to be rectangular, trapezoid, parabola or any other shape for design purposes the compressive strength of concrete in the structure shall be assumed to be 0.67 timed the characteristic strength.

(4) The tensile strength of concrete is ignored.

(5) The stresses in reinforcement are derived from representive stress-strain curve for the type of steel used.

(6) The maximum strain in the tension reinforcement in the section at failure shall not be less than

$$E_s = \frac{fy}{1.15E_s} + 0.002$$

fy = charecteristic strength of steel

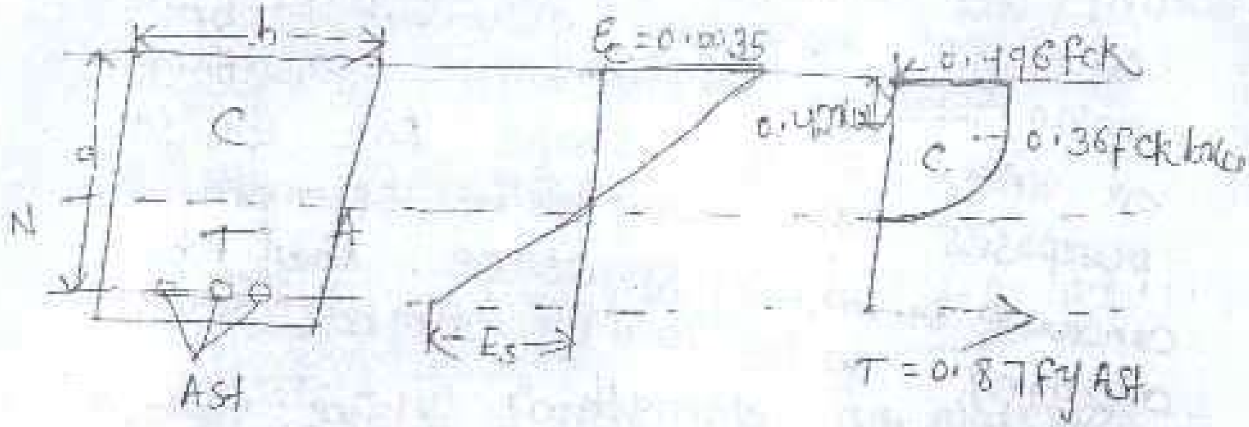
1 June 2081

Es = Young's modulus of steel

E = 2×10^5 N/mm2

Figure ...

Derivation formula for balanced singly reinforced rectangular beam :-



TO find N.A

Total Compression = total tension

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

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

TO find Lever Arm (z)

$$\boxed{z = d - 0.42 x_u}$$

TO find out Moment of Resistance

MR = total compression X LA

(or)

total tension X LA

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

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

$\Rightarrow 0.36 f_{ck} \frac{x_u}{d} \left(1 - 0.42 \frac{x_u}{d}\right) b$

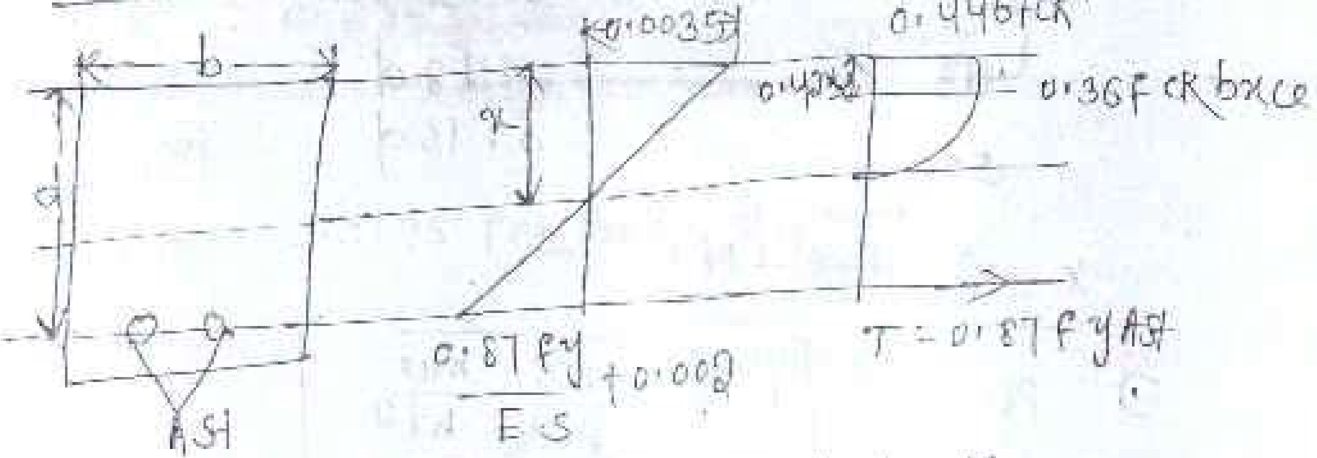
(2)

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

$= 0.87 f_y A_{st} \left(d - 0.42 \left(\frac{0.87 f_y A_{st}}{0.36 f_{ck} b} \right) \right)$

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

Maximum depth of N.A



By the geometry of the strain dia

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

$$\frac{x_{u\,max}}{d} = \frac{0.0035}{\frac{0.87 f_y}{2 \times 10^5} + 0.002 + 0.0035}$$

$$\frac{x_{umax}}{d} = \frac{700}{1100 + 0.87 f_y}$$ 2 June 2021

f_y (N/mm^2)	$\frac{x_{umax}}{d}$
250	0.53
415	0.48
500	0.46

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

$x_{umax} = 0.53d$

f_y (N/mm^2)	x_{umax}
250	0.53d
415	0.48d
500	0.46d

% of steel (P_t)

(i) $$P_t = 50\left[\frac{1-\sqrt{1-\frac{4.6}{f_{ck}}\frac{M_u}{bd^2}}}{f_y/f_{ck}}\right]$$

(ii) $$P_{tlimit} = 50\left[\frac{1-\sqrt{1-\frac{4.6}{f_{ck}}\frac{M_{ulimit}}{bd^2}}}{f_y/f_{ck}}\right]$$

If $x_u < x_{umax}$, the section is under reinforced section

$$M_R = 0.87 f_y A_{st} d\left[1-\frac{A_{st} f_y}{bd f_{ck}}\right]$$

If $x_u > x_{umax}$, the beam is over reinforced section.

$$MR_{limit} = 0.36 f_{ck} b x_u \left(d - 0.42 \frac{x_{umax}}{d}\right) d$$

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

Grade of steel	$\frac{x_{umax}}{d}$	M_{ulimit}
Fe 250	0.53	$0.148 f_{ck} bd^2$
Fe 415	0.48	$0.138 f_{ck} bd^2$
Fe 500	0.46	$0.133 f_{ck} bd^2$

For balanced section

$$M.R = 0.87 f_y A_{st} d \left[1 - \frac{A_{st} f_y}{bd f_{ck}}\right]$$

(or)

$$M_{ulimit} = 0.36 f_{ck} bd^2 \cdot \frac{x_{umax}}{d} \times \left(1 - 0.42 \frac{x_{umax}}{d}\right)$$

1Q A rectangular reinforced conc. beam has a width of 200 mm & effective depth 460 mm is reinforced with 2 bars of 20 mm dia bar. The materials are M 20 grade concrete & Fe415 grade of steel. Calculate the ultimate moment of resistance of the section.

Soln:

given data

Width of beam(b) = 200mm

Effective depth = 460mm

$Ast = 2 \times \frac{\pi}{4} \times 20^2 = 628.318 mm^2$

for M20 grade conc. $f_{ck} = 20 N/mm^2$

Fe415 steel $f_y = 415 N/mm^2$

Step-1

Depth of N.A (x_u)

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

$$= \frac{0.87 \times 415 \times 628}{0.36 \times 20 \times 200}$$

$$= 157.45 mm$$

Max^m depth of N.A ($x_u max$)

$x_u max = 0.48 d$

$= 0.48 \times 460 = 220.8 mm$

$x_u < x_u max$ so under reinforced section.

Step-2

ultimate moment of Resistance

$$M_u = 0.87 f_y \, Ast \, d \left[1 - \frac{Ast \, f_y}{bd \, f_{ck}}\right]$$

$= 0.87 \times 415 \times 628 \times 460 \left[1 - \frac{628 \times 415}{200 \times 460 \times 20}\right]$

$= 89526918.39$ N mm

$= 89.52$ kN.m

Q2 A singly reinforced rectangular beam of width 230mm & 460mm effective depth is reinforced with 5 nos of 20mm dia bar. The materials are M20 grade fe415. Calculate ultimate moment of Resistance of section.

3 June 2021

Sol given data :—

width of beam (b) = 230mm

Effective depth (d) = 460mm

$A_{st} = 5 \times \frac{\pi}{4} \times 20^2 = 1570.79$ mm

for M20 grade $f_{ck} = 20$ N/mm²

Fe415 $f_y = 415$ N/mm²

step-1

Depth of N.A x_u

$$x_u = \frac{0.87 \times 415 \times 1570}{0.36 \times 20 \times 230} = 342.29 \text{ mm}$$

max^m depth of N.A (x_{umax})

$x_{umax} = 0.48d = 0.48 \times 460 = 220.8$ mm

step- $x_u > x_{umax}$ so the beam is over reinforced section.

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

$= 0.138 \times 20 \times 230 \times 460^2$

$= 134323680$ Nmm

$= 134.32$ kNm

22. A reinforced concrete beam 300mm width is reinforced with $1436 mm^2$ of Fe415 HYSD bars at an effective depth of 500 mm If M20 grade concrete is used estimate the moment of resistance of the section by LSM

Sol width of beam(b) = 300mm

Effective depth = ~~1436 mm²~~ $500 mm^2$

$A_{st} = 1436 mm^2$

M20 grade (f_{ck}) $= 20 N/mm^2$

Fe415 $= 415 N/mm^2$

Step-1

$$x_u = \frac{0.87 \times 415 \times 1436}{0.36 \times 20 \times 300}$$

$= 240.03$ mm.

Max^m depth of N.A x_{umax}

$0.48 \times 500 = 240$ mm.

$x_u = x_{umax}$ so the beam is balanced section.

$MR = 0.138 f_{ck} bd^2 = 0.138 \times 20 \times 300 \times 500^2$

$= 207000000 \text{ Nm}$

$= 207 \text{ KNm}.$

To find out steel area for a given factored Moment :-

Step-1

For a given factored moment (1.5X working moment) & assumed width of the section.

Step-2

Find out depth (if depth not given)

$$d = \sqrt{\frac{M_{ulimit}}{F_{ck} \times b \times \text{constant}}}$$

$M_{ulimit} = 0.148 f_{ck} bd^2$

$= 0.138 f_{ck} bd^2$

$= 0.133 f_{ck} bd^2.$

If depth given :—

calculate $M_{u\,limit}$ value according to this value. compare with 'M_u' choose the section.

If $M_{ulimit} > M_u$. it is under reinforced section.

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

(iii) If $M_{ulim} = M_u$, then it is balance section.

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

3Q Determine the area of reinforcement required for a singly reinforced conc. section having a width of 300mm & an effective depth of 600 mm to resist a factored moment of 200 KN m. The materials are M20 grade conc. & HYSD reinforcement of grade Fe415.

<u>data given</u>

width of (b) = 300 mm

Effective depth (d) = 600 mm.

factored moment (M_u) = 200 KNm
$= 200 \times 10^6$ Nm

M20 grade (f_{ck}) = 20 N/mm²

HYSD Fe415 (f_y) = 415 N/mm²

<u>step-1</u>

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

$= 0.138 \times 20 \times 300 \times 600^2$

$= 298080000$ Nm.

$= 298$ KNm

$Mu\ limit = 298$ KNm

$Mu = 200$ KNm

Mulimit > Mu so It is under reinforced section.

Step-2

find steel area

$$Mu = 0.87\ Ast\ fyd \left[1 - \frac{fy\ Ast}{Fck\ bd}\right]$$

$$200 \times 10^6 = 0.87 \times Ast \times 415 \times 600 \left[1 - \frac{415 Ast}{20 \times 300 \times 600}\right]$$

$$\Rightarrow 200 \times 10^6 = 2166.30\ Ast \left(1 - 1.15 \times 10^{-4}\ Ast\right)$$

$$\Rightarrow 200 \times 10^6 = 216630\ Ast - 24.91 Ast$$

4 June 2021

25. Determine the area of reinforcement required for a singly reinforced concrete section having a width of 230 mm resist a factored moment of 300 KN m. The materials are M20 grade conc. & HYSD reinforcement of grade Fe 415.

Soln Given data:-

width of beam (b) = 230 mm

factored moment = 300 KN m

fck = 20 N/mm2

fy = 415 N/mm2

Step-1

Find effective depth of beam (d).

$$d = \sqrt{\frac{Mu\,limit}{fck \times b \times constant}}$$

$Mu\,limit = 0.138\, fck\, bd^2$

$$d = \sqrt{\frac{300 \times 10^6}{20 \times 230 \times 0.138}} = 687.45 \simeq 688\,mm$$

Step-2

$Mu\,limit = 0.138\, fck\, bd^2$

$= 0.138 \times 20 \times 230 \times 688^2$

$= 300$ KN m

$Mu = 300\ KNm$

$Mulimit = 300\ KNm$

$Mu = mulimit$ it is balanced section.

step-3

Area of steel

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

$$0.48 = \frac{0.87 \times 415 \times A_{st}}{0.36 \times 20 \times 230 \times 688}$$

$$546877.44 = 0.87 \times 415\ A_{st}$$

$$A_{st} = \frac{546877.44}{0.87 \times 415} = 1514\ mm^2$$

Q A singly reinforced beam is subjected to a bending moment of 36 KNm at working loads. The width of beam is 200 mm find the depth & steel area of the section. The materials are M20 grade conc. & HYSD reinforcement.

Given data :-

bending moment = 36 KNm at working loads

factored moment = (1.5 × working loads)

$(1.5 \times 36) = 54\ KNm$

width of beam (b) = 200mm

M_{20} grade $f_{ck} = 20$ N/mm²

HYSD Fe415 $f_y = 415$ N/mm²

step-1

$$d = \sqrt{\frac{Mu}{fck \times b \times \text{Constant}}}$$

$$= \sqrt{\frac{54 \times 10^6}{20 \times 200 \times 0.138}}$$

$= 312.77 \approx 313$mm

$Mu_{limit} = 0.138 \times 20 \times 200 \times 313^2$

$= \cancel{53733888}$ ~~Nmm~~

$= 54078888$ Nmm $= 54$ KNm

$Mu = 54$ KNm

$Mu_{limit} = 54$ KNm

then the beam is balanced section.

step-2

Area of steel

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

$$0.48 = \frac{0.87 \times 415 A_{st}}{0.36 \times 20 \times 200 \times 313}$$

$$\frac{216345.6}{0.87 \times 415} = A_{st}$$

$A_{st} = 599.21$ mm²

~~216·345~~ = ~~0·87 × 415 Ast~~

~~Ast =~~ ~~5·5 3415·8~~
~~0·87 × 415~~

$0·48 = \frac{0·87 × 415 × Ast}{0·36 × 20 × 230 × 688}$

$\frac{546877·44}{0·87 × 415} = Ast$

⇒ ~~1514 mm²~~ = Ast

10. A singly reinforced concrete beam subjected to a bending moment 56 kNm at working loads. The width of beam is 230 mm balanced design. Find depth & steel area. The materials are M20 grade conc. & HYSD reinforcement.

Given data :-

Moment = 56 kNm

$M_u = 1·5 × 56 = 84$ kNm

width of beam (b) = 230 mm

M20 grade f_{ck} = 20 N/mm²

f_y = 415 N/mm²

Step - 1

$d = \sqrt{\frac{84 × 10^6}{20 × 230 × 0·138}}$

= 363·76 mm

Step 2

Area of steel

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

$$0.48 = \frac{0.87 \times 415\ A_{st}}{0.36 \times 20 \times 230 \times 354}$$

$A_{st} \times 0.87 \times 415 = 216345.6$

$$\Rightarrow \frac{289336.32}{0.87 \times 415} = A_{st}$$

$\Rightarrow A_{st} = 801.37\ mm^2$

Q) A rectangular beam 230 mm wide and 250 mm effective depth is reinforced with 4 no 16 mm diameter bars. Find out the depth of neutral axis and specify the type of beam. The materials are M20 grade conc. and HYSD reinforcement of grade Fe415. Also find out the depth of neutral axis if the reinforcement is increased to 4 no. 20 mm diameter bars.

Sol) Given data :-

Width of beam (b) = 230 mm

Effective depth (d) = 520 mm

no of bars = 4

dia = 16 m.m

$A_{st} = 804\ mm^2$

Case-1

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

Step 1

$x_u = \frac{0.87 \times f_y \times A_{st}}{0.36 \times 20 \times 230} = \frac{0.87 \times 415 \times 942.47}{0.36 \times 20 \times 230}$

$= 205.48$

Step-2

$x_{umax} = 0.48 \times 460 = 220.8$

$x_u < x_{umax}$ so the beam is underreinforced section.

Step-3

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

$= 0.87 \times 415 \times 942.47 \times 460 \left[1 - \frac{942.47 \times 415}{230 \times 460 \times 20}\right]$

$= 126672921.5 \text{ N·mm}$

$= 126.67 \text{ kNm}$

Case-2 $A_{st} = 5 \times \frac{\pi}{4} \times 20^2 = 1570.79 \text{ mm}^2$

Step-1

$x_u = \frac{0.87 f_y A_{st}}{0.36 \times 20 \times 230} = 342.47$

Step-2 $x_{umax} = 0.48 \times 460 = 220.8$

Step-1

depth of N.A (x_u)

$$x_u = \frac{0.87 f_y A_{st}}{0.36 f_{ck} b} = \frac{0.87 \times 415 \times 804}{0.36 \times \cancel{415}\, 20 \times 230}$$

$= 175.29$ mm

Step-2 Max^m depth of N.A ($x_{u max}$)

$0.48d = 0.48 \times 520 = 249.6$mm

$x_u < x_{u max}$ so the beam is in under reinforced section.

case 2

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

~~step~~ N.A (x_u) depth of

$$x_u = \frac{0.87 \times 415 \times 1256.63}{0.36 \times 20 \times 230} = 273.97\text{mm}$$

6Q A singly reinforced rectangular beam of width 230 mm and 460 mm effective depth is reinforced with 3 no 20 mm diameter bars. find out the factored moment of resistance of the section. The materials are M_{20} grade conc. and HYSD reinforcement of grade fe 415. Also find out the factored moment of resistance if it is reinforced with 5 no 20 mm dia.

Sol Given data:-

width of beam (b) = 230mm

Effective depth (d) = 460mm

f_{ck} = 20 N/mm^2

f_y = 415 N/mm^2

$x_{u\,max} < x_{u}$ so the beam is over reinforced section.

Step-3

$M_{u\,limit} = 0.138 \times f_{ck}\, bd^2$

$= 0.138 \times 20 \times 230 \times 460^2$

$= 134323680$ Nmm

$= 134.32$ kNm

1Q A rectangular cantilever beam of size 230 mm width × 500 mm effective depth is subjected to a bending moment of 80 kN·m at working loads find the steel area required. The materials are M20 grade concrete and reinforcement of grade Fe415.

Sol

Given data:-

width of beam (b) = 230 mm

Effective depth (d) = 500 mm

bending moment = 80 kNm

factor moment = 1.5×80 = 120 kN m

f_{ck} = 20 N/mm²

$fy = 415 \ N/mm^2$

Step-1

$Mu\ limit = 0.138\ fck\ bd^2$

$= 0.138 \times 20 \times 230 \times 500^2$

$= 158.70$ KNM

$Mu < Mu\ limit$ so the beam under reinforced section.

$$Mu = 0.87\ Ast\ fy\ d \left[1 - \frac{fy\ Ast}{fck\ bd}\right]$$

$$= 120 \times 10^6 = 0.87 \times Ast \times 415 \times 500 \left[1 - \frac{415 \times Ast}{20 \times 230 \times 500}\right]$$

$\Rightarrow 120 \times 10^6 = 180525\ Ast\ (1 - 1.80 \times 10^{-4}\ Ast)$

$\Rightarrow 120 \times 10^6 = 180525\ Ast - 32.49\ Ast^2$

$\Rightarrow 32.49\ Ast^2 - 180525\ Ast + 120 \times 10^6 = 0$

$\Rightarrow Ast = 4784.33\ mm^2$

7 June 2021

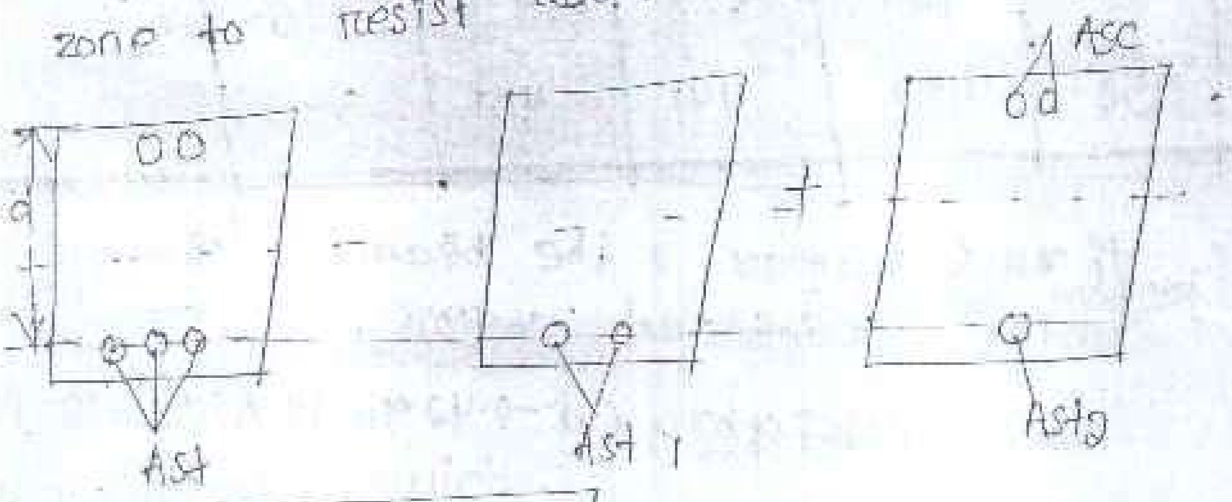
—ooo—

Dobly reinforced Beam

For design moment 'Mu' if the size of the rectangular beam section is fixed and limiting moment of resistance of singly reinforced section is less than 'M' There are two method to design such beam :-

① Increase the conc. mix to increase the capacity of section ?

② Reinforcement are provided in compression zone to resist additional moment.



$$\boxed{M_u = M_{u\,limit} + M_2}$$

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

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

$$\boxed{A_{st\,limit} = \frac{M_{u\,limit}}{0.87 f_y (d - 0.42\, x_{u\,max})}}$$

$$A_{sc} = \frac{M_{u2}}{f_{sc}(d-d')}$$

To find out depth of N.A

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

stress in compression zone

f_y N/mm²	d'/d 0.05	0.1	0.15	0.2
250	217	217	217	217
415	355	353	342	329
500	424	412	395	370
550	458	441	419	380

If $x_u < x_{umax}$, the beam is in under reinforced section.

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

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

If $x_u > x_{umax}$, over reinforced beam.

$$M_u = M_{u\,limit} + f_{sc} A_{sc} (d - d')$$

(over & balanced)

Types of problems

Type-1

To find out the moment of Resistance of the given section.

$$C = T$$

$$0.36 f_{ck} b x_u + A_{sc}(f_{sc} - f_{cc}) = 0.87 f_y A_{st}$$

$$x_{umax} = ?$$

If $x_u < x_{umax}$ the beam is underreinforced section

If $x_u > x_{umax}$ the beam is over reinforced section

Type-2

find out reinforcement & factored moment :—

① Find out $M_{ulimit} = 0.148 f_{ck} b d^2$

for 415 $= 0.138 f_{ck} b d^2$

for 500 $= 0.133 f_{ck} b d^2$

$$A_{st\,limit} = \frac{M_{ulimit}}{0.87 f_y (d - 0.42 x_{umax})}$$

② $M_{u2} = M_u - M_{ulimit}$

③ find compression zone steel area

$$A_{sc} = \frac{M_{u2}}{f_{sc}(d-d')}$$

Step-4

Area of steel in tensile

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

$$\boxed{A_{st} = A_{st\,lim} + A_{st2}}$$

8 June 2021

18) A doubly reinforced beam section is 250 mm wide & 450 mm deep to the centre of the tensile reinforcement. It is reinforced with 2 bars of 16mm dia. as compression reinforcement at an effective cover of 50mm & 4 bar of 25 mm dia bar as tensile steel. calculate the ultimate moment of resistance. use M20 grade conc & HYSD reinforcement

Given data:-

Width of beam (b) = 250mm

Effective depth (d) = 450mm

$A_{sc} = 2 \times \frac{\pi}{4} \times 16^2 = 402\ mm^2$

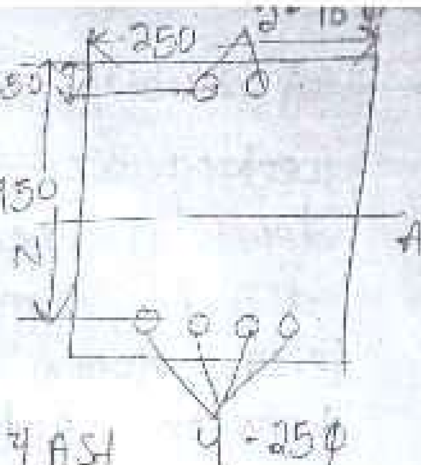
$A_{st} = 4 \times \frac{\pi}{4} \times 25^2 = 1963.49 \approx 1964 mm^2$

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

$f_y = 415 N/mm^2$

$\frac{d'}{d} = \frac{50}{450} = 0.1$

$F_{SC} = 353\ N/mm^2$



Step 1

To find depth of N.A

$C = T$

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

$\Rightarrow 0.36 \times 20 \times 250\, x_u + 353 \times 402 = 0.87 \times 415 \times 1964$

$\Rightarrow 1800 x_u + 141906 = 709102.2$

$\Rightarrow 1800 x_u = 709102.2 - 141906$

$\Rightarrow x_u = \dfrac{709102.2 - 141906}{1800} = 315\ mm$

$x_{umax} = 0.48 d$

$= 0.48 \times 450 = 216\ mm$

$x_u > x_{umax}$ the beam is in over reinforced section.

Step-2

To find ultimate moment of Resistance (M_u)

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

$M_{ulimit} = 0.138 \times 20 \times 250 \times 450^2$

$= 139.72\ kNm$

$M_u = 139.72 \times 10^6 + 353 \times 402 \times (450 - 50)$

$= 196.48\ kNm$

2. Q A doubly reinforced conc. beam having rectangular section 250 x 540 mm overall depth is reinforced with 2 bars of 12mm dia in compression side of effective cover 40mm & 4 bars 20mm dia in tension side. use M20 conc. & Fe415 steel. calculate flexural strength of the section. Take effective depth cover 40 mm both side.

Given data :-

Width of beam = 250mm

overall Depth (D) = 540mm

Effective cover (d') = 40mm

$d = 540 - 40 = 500mm$

$\frac{d'}{d} = \frac{40}{500} = 0.08$ $f_{sc} = 353 N/mm^2$

$A_{st} = 1256 mm^2$

M20 grade $f_{ck} = 20 N/mm^2$ $A_{sc} = 226 mm^2$

Fe415 $(f_y) = 415 N/mm^2$

Step-1

$M_{u\,limit} = 0.138 f_{ck} b d^2$

$= 0.138 \times 20 \times 250 \times 500^2$

$= 172.5$ kNm

$x_{u\,max} = 0.48 d = 0.48 \times 500$

$= 240 mm$

$$Ast\,1\,limit = \frac{Mu\,limit}{0.87 f_y (d - 0.42\,x_{u\,max})}$$

$$= \frac{172.5 \times 10^6}{0.87 \times 415 (500 - 0.42 \times 0.48 \ldots)}$$

$$= 1196.8 \simeq 1197\ mm^2$$

$$Ast = 1256\ mm^2$$

$$Ast_2 = \frac{fsc \times Asc}{0.87 f_y} = \frac{353 \times 226}{0.87 \times 415}$$

$$= 220.96 \simeq 221\ mm^2$$

$$Ast = Ast_1 + Ast_2$$

$$Ast_1 = Ast - Ast_2$$

$$= 1256 - 221 = 1035\ mm^2$$

~~Step 2~~

To find x_u

$$0.36 f_{ck} b x_u + fsc\,Asc = 0.87 f_y Ast$$

$$x_u = \frac{\cancel{0.87 f_y Ast}}{0.36 f_{ck} b + fsc\,Asc}$$

$$= 0.36 \times 20 \times 250\, x_u + 353 \times 226 = 0.87 \times 415 \times 1256$$

$$1800\, x_u + 79778 = 453478.8$$

$$1800\, x_u = 453478.8 - 79778$$

$$x_u = \frac{453478.8 - 79778}{1800} = 207\ mm$$

$x_{umax} = 240$ $x = 207$

$x_u < x_{umax}$ so it is undr rienforced Seetion.

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

$= 0.36 \times 20 \times 250 \times 207.81 (500 - 0.42 \times 207.81)$
$+ 226 \times 353 (500 - 40)$

$= 191079022.9$ Nm

$= 191$ KNm

9 June 2021

3Q

A reetangular beam of size 230mm wide x 500mm effeetive depth is subjeeted to a factored moment of 200 kNm. Find the reinforcement for flexure. The materials are M20 grade conc. & fe415 steel. Take cover = 50mm.

Soln

Given data :-

Width of beam (b) = 230mm

Effeetive depth (d) = 500mm

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

$f_y = 415\ N/mm^2$

factored moment (M_u) = 200 KNm

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

$= 158.7\ KNm$

$Mu_{limit} < Mu$ so the beam is design as doubly reinforcement.

Step-1

$Mu_{limit} = 158.7\ KNm$

$Mu = 200\ KNm$

$Mu_2 = Mu - Mu_{limit}$

$= 200 - 158.7 = 41.3\ KNm$

Assume $d' = 50mm$

$\frac{d'}{d} = \frac{50}{500} = 0.1 \quad f_{sc} = 353\ N/mm^2$

$A_{sc} = \frac{Mu_2}{f_{sc}(d-d')} = \frac{41.3 \times 10^6}{353(500-50)}$

$= 260mm^2$

$A_{st_2} = \frac{A_{sc} f_{sc}}{0.87 f_y} = \frac{260 \times 353}{0.87 \times 415} = 254mm^2$

$x_{u\,max} = 0.48 \times 500 = 240mm$

$A_{st\,limit} = \frac{Mu_{limit}}{0.87 f_y (d - 0.42\ x_{u\,max})}$

$= \frac{158.7 \times 10^6}{0.87 \times 415 \times (500 - 0.42 \times 240)} = 1101.08mm^2$

$A_{st} = A_{st\,limit} + A_{st_2} = 1355.08\ mm^2$

$A_{sc} = 260\ mm^2$

provide 2 bars 16 mm dia $\quad A_{sc} = 2 \times \frac{\pi}{4} \times 16^2$

$= 402\ mm^2$

$A_{st} = 1355$ provide 5 no 20 mm dia bar

$A_{st} = 5 \times \frac{\pi}{4} \times 20^2 = 1570\ mm^2$

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

$\Rightarrow 0.36 \times 20 \times 230 x_u + 353 \times 402 = 0.87 \times 415 \times 1570$

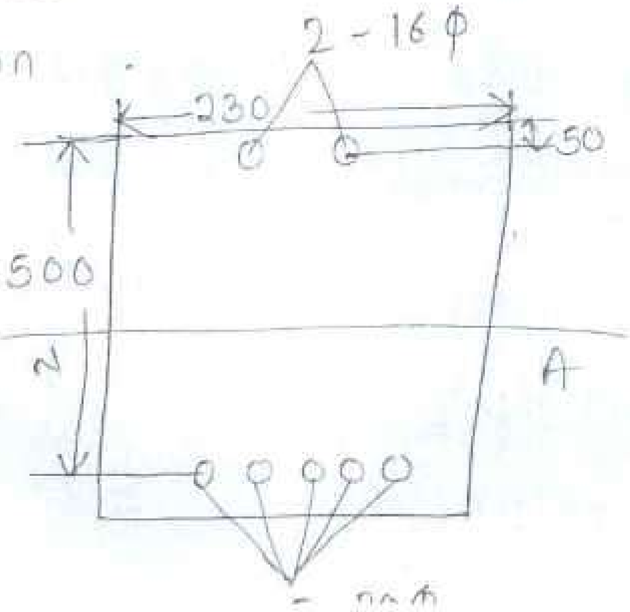
$\Rightarrow 1656 x_u + 141906 = 566848.5$

$\Rightarrow 1656 x_u = 566848.5 - 141906$

$$\Rightarrow x_u = \frac{566848.5 - 141906}{1656}$$

$= 256\ mm^2$

$x_u > x_{umax}$ the beam is overreinforced section



10 June 2021

$\underline{4Q}$ find the factored moment of resistance of a beam section 300mm wide x450mm effective depth reinforced with 2-20mm diameters bars as compression reinforcement at an effective cover of 50mm and 4-25 mm diameter bars as tension reinforcement The materials are M20 grade concrete and HYSD reinforcement of grade Fe415.

Given data:-

Width of beam = 300mm

Effective depth = 450mm

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

$= 628\ mm^2$

$Ast = 4 \times \frac{\pi}{4} \times 25^2 = 1963\ mm^2$

$d' = 50\ mm$

$fck = 20\ N/mm^2$

$fy = 415\ N/mm^2$

$fsc = \frac{d'}{d} = \frac{50}{450} = 0.1 = 353\ N/mm^2$

Step-1 $Mulimit = 0.138\, fck\, bd^2 = 167.67\ kN\cdot m$

$= 0.138 \times 20 \times 300 \times 450^2$

$Ast2 = \frac{Asc\ fsc}{0.87fy} = \frac{628 \times 353}{0.87 \times 415} = 613.9 \approx 614\ mm^2$

$Astlimit = Ast - Ast2$

$= 1963 - 614$

$= 1349$

$Ast = 614 + 1349 = 1963 mm^2$

Step 2

x_u

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

$\Rightarrow 0.36 \times 20 \times 300 x_u + 353 \times 628 = 0.87 \times 415 \times 1963$

$\Rightarrow 2160 x_u + 221684 = 708741.15$

$\Rightarrow 2160 x_u = 708741.15 - 221684$

$\Rightarrow x_u = \frac{487057.15}{2160}$

$= 225.48$

$x_{umax} = 0.48 \times d = 0.48 \times 450 = 216 mm$

$x_u > x_{umax}$ so the beam is over reinforced section.

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

$= 167.67 \times 10^6 + 353 \times 628 (450 - 50)$

$= 256343600 \ N \cdot mm$

$= 256.34 \ kN \cdot m$

10 jun ...

5Q Design a rectangular beam for an effective span of 6mt. The super-imposed load is 80 kN/m and size of the beam is limited to 30cm x 70cm overall. use M20 mix and Fe415 grade of steel.

Given data:-

Length of span = 6mt

super-imposed load = 80 kN/m

F_{ck} = 20 N/mm^2

f_y = 415 N/mm^2

width of beam 30cm = 300mm

overall depth = 70cm = 700mm

Dead load of beam = bd x 25

= 0.3 x 0.7 x 25 = 5.2 kN/m

Total load of beam = self wt of beam + super-imposed load

= 5.25 + 80

= 85.25 kN/m

factor load = (1.5 x 85.25) = 128

factored moment = $\frac{wl^2}{8}$ = $\frac{128 \times 16^2}{8}$

= 576 kN.m

Let Effective cover = 40mm

Effective depth = 700 - 40 = 660mm

$f_{sc} = \frac{d'}{d} = \frac{40}{660} = 0.06$ = 353 N/mm^2

Step-1

Limiting moment

$0.138\, f_{ck} b d^2 = 0.138 \times 20 \times 300 \times 600^2$

$= 360\,676\,800$ N·mm

$= 360.67$ KNm

$M_u = 567 > M_{ulimit} = 360$ so the design doubly reinforced.

$M_{u2} = M_u - M_{ulimit}$

$= 576 - 360 = 216$ KNm

$$A_{SC} = \frac{M_{u2}}{f_{sc}(d-d')} = \frac{216 \times 10^6}{353 \times (660-40)}$$

$= 986.93\ mm^2$

$$A_{st_2} = \frac{A_{SC} \times f_{SC}}{0.87 \times f_y} = \frac{986.93 \times 353}{0.87 \times 415}$$

$= 964.42 = 965\ mm^2$

$x_{umax} = 0.48 \times 660 = 316.8\ mm = 317\ mm$

$$A_{stlimit} = \frac{M_{ulimit}}{0.87 f_y (d - 0.42\, x_{umax})}$$

$$= \frac{360.67 \times 10^6}{0.87 \times 415 (660 - 0.42 \times 317)}$$

$= 1896\ mm^2$

$Ast = Ast_{limit} + Ast_2$

$= 1986 + 965 = 2861 \ mm^2$

$ASC = 986.93$ provide 4 bars 20 ϕ

$ASC = 4 \times \frac{\pi}{4} \times 20^2 = 1256 \ mm^2$

$Ast = 2861$ provide 6 bars 25 ϕ

$Ast = 6 \times \frac{\pi}{4} \times 25^2 = 2945.24 \ mm^2$

Step-2

To find x_u

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

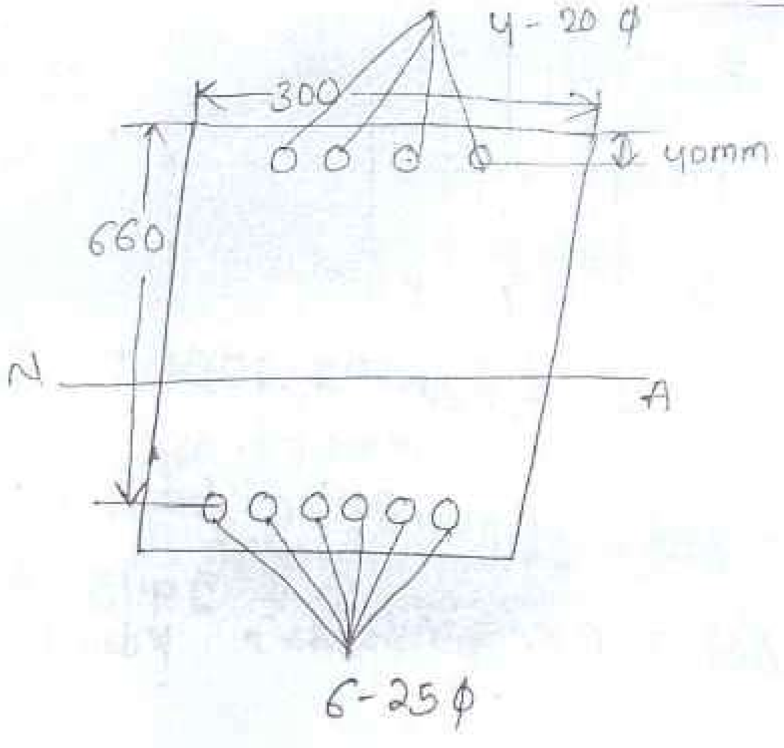
$\Rightarrow 0.36 \times 20 \times 300 x_u + 353 \times 1256.63 = 0.87 \times 415 \times 2945.24$

$\Rightarrow 2160 x_u + 443495.08 = 1063378.9$

$\Rightarrow 2160 x_u = 1063378.9 - 443495.08$

$\Rightarrow x_u = \frac{619883.82}{2160} = 286.9 \ mm$

$x_{umax} > x_u$ the beam is under reinforced section.



11 June 2021

A doubly reinforced rectangular beam 300mm wide & 450mm effective depth having 3 no 12 mm dia bar at compression side. at an effective cover of 40mm & 5 no of 20mm dia are tension side. Calculate factored moment & also specify type of beam. The materials are M_{20} grade concrete & mild steel reinforcement

Given data:-

width of beam 300 mm

Effective depth = 450 m.m

Effective cover = 40 m.m.

$Asc = 3 \times \frac{\pi}{4} \times 12^2 = 339.29\ mm^2$

$Ast = 5 \times \frac{\pi}{4} \times 20^2 = 1570.79 = 1571 mm^2$

M20 grade fck = $20 N/mm^2$

Fe250 fy = $250 N/mm^2$

$\frac{d'}{d} = \frac{40}{450} = 0.08 \simeq 0.1$

$FSC = 217\ N/mm^2$

Step-1

To find out depth of N.A

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

$\Rightarrow 0.36 \times 20 \times 300 x_u + 217 \times 339.29 = 0.87 \times 250 \times 1571$

$\Rightarrow 2160 x_u + 73625.93 = 341692.5$

$\Rightarrow 2160 x_u = 341692.5 - 73625.93$

$\Rightarrow x_u = \frac{268066.57}{2160} = 124.10\ mm$

$x_{umax} = 0.53d = 0.53 \times 450 = 238.5\ mm$

$x_u < x_{umax}$ so th beam is underreinforceg section.

Step-2

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

$= 0.36 \times 20 \times 300 \times 124.10 (450 - 0.42 \times 124.10) + 339.29 \times 217 (450 - 40)$

$= 136840216.5\ Nm$

$= 136.8\ kNm$

mm^2

$\frac{d'}{d} = \frac{40}{450} = 0.08 \simeq 0.1$

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

step-1

To find out depth of N.A

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

$\Rightarrow 0.36 \times 20 \times 300 x_u + 217 \times 339.29 = 0.87 \times 250 \times 1571$

$\Rightarrow 2160 x_u + 73625.93 = 341692.5$

$\Rightarrow 2160 x_u = 341692.5 - 73625.93$

$\Rightarrow x_u = \frac{268066.57}{2160} = 124.10\ mm$

$x_{umax} = 0.53 d = 0.53 \times 450 = 238.5\ mm$

$x_u < x_{umax}$ so th beam is underreinforced section.

step-2

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

$= 0.36 \times 20 \times 300 \times 124.10 (450 - 0.42 \times 124.10) + 339.29 \times 217 (450 - 40)$

$= 136840216.5\ Nm$

$= 136.8\ kNm$

$= 268\ KNm$

$x_u > x_{ulimit}$ so the beam design as doubly reinforced beam.

$\frac{d'}{d} = \frac{50}{500} = 0.1 \quad fsc = 217\ N/mm^2$

$$Ast_{limit} = \frac{Mu_{limit}}{0.87 fy\,(d - 0.42\, x_{umax})}$$

$x_{umax} = 0.53 \times 550 = 291.5\ mm$

$$Ast_{limi} = \frac{268 \times 10^6}{0.87 \times 250 (550 - 0.42 \times 291.5)}$$

$= 2881.82\ mm^2$

$Mu = Mu_{limit} + Mu_2$

$\Rightarrow Mu_2 = Mu - Mu_{limi}$

$= 656 - 268 = 388\ KNm$

$$Asc = \frac{Mu_2}{fsc\,(d - d')} = \left(\frac{388 \times 10^6}{217\,(550 - 50)}\right)$$

$= 3576\ mm^2$

$$Ast_2 = \frac{Asc\, fsc}{0.87 fy} = \frac{3756 \times 217}{0.87 \times 250} = 3568\ mm^2$$

$Ast = Ast_{lim} + Ast_2 = 6449.82\ mm^2$

$Asc = 3576\ mm^2$ provide 6 bar 30 ϕ

$Asc = 6 \times \frac{\pi}{4} \times 30^2 = 4241.15\ mm^2$

12 June 2021 O.S.M

18. Design rectangular beam for an effective span of 8mt The super-imposed Load is 50 KN/m & size of the beam is 300mm X550mm an effective depth use M20 grade concrete & Fe250 steel.

soln given data :-

width of beam (b) = 300mm

Effective depth (d) = 550mm

d' = 50mm

super imposed load = 50 KN/m

span length = 8mt

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

$f_y = 250 N/mm^2$

soln super imposed load = 50 KN/mm

Self wt of beam = $b \times D \times 25$

$= 0.3 \times 0.6 \times 25 = 4.5$ KN/m

$D = 550 + 50 = 600$ mm

Total load = 50 + 4.5 = 54.5 KN/m

factored load = 1.5×54.5 = 81.75 KN/m

= 82 KN/m

factored moment $= \frac{wl^2}{8} = \frac{82 \times 8^6}{8}$

= 656 KN m

Step 1

$M_{u\,limit} = 0.148 f_{ck} b d^2$

$= 0.148 \times 20 \times 300 \times 550^2$

$= 268 \ kNm$

$x_u > x_{ulimit}$ so the beam design as doubly reinforced beam.

$\frac{d'}{d} = \frac{50}{500} = 0.1$ $f_{sc} = 217 \ N/mm^2$

$$Ast_{limit} = \frac{Mu_{limit}}{0.87 f_y (d - 0.42 x_{umax})}$$

$x_{umax} = 0.53 \times 550 = 291.5 \ mm$

$$Ast_{limi} = \frac{268 \times 10^6}{0.87 \times 250 (550 - 0.42 \times 291.5)}$$

$= 2881.82 \ mm^2$

$Mu = Mu_{limit} + Mu_2$

$\Rightarrow Mu_2 = Mu - Mu_{limi}$

$= 656 - 268 = 388 \ kNm$

$$Asc = \frac{Mu_2}{f_{sc}(d-d')} = \left(\frac{388 \times 10^6}{217(550-50)}\right)$$

$= 3976 mm^2$

$$Ast_2 = \frac{Asc \, f_{sc}}{0.87 f_y} = \frac{3756 \times 217}{0.87 \times 250} = 3568 mm^2$$

$Ast = Ast_{lim} + Ast_2 = 6449.82 \ mm^2$

$Asc = 3576 \ mm^2$ provide 6 bar 30 ϕ

$Asc = 6 \times \frac{\pi}{4} \times 30^2 = 4241.15 \ mm^2$

$A_{st} = 6449.82 mm^2$ provide 7 bar 35 ϕ

$A_{st} = 7 \times \frac{\pi}{4} \times 35^2 = 6734.78 \ mm^2$

Step-2:

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

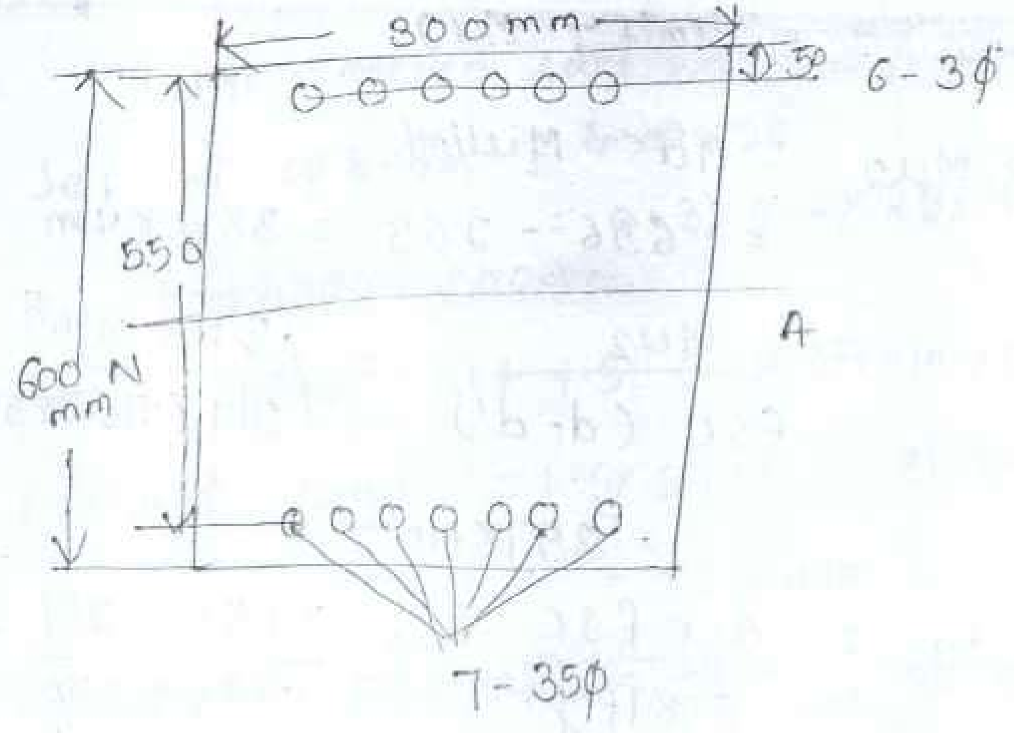
$= 0.36 \times 20 \times 300 x_u + 217 \times 4241.15 = 0.87 \times 250 \times 6734.78$

$= 2160 x_u + 920329.55 = 1464814.65$

$= 2160 x_u = \frac{544485.1}{2160}$

$x_u = 252.07 mm$

$x_{umax} > x_u$ So the beam is under reinforced section.



$$Asc = \frac{Mu_2}{FSC(d-d')} = \frac{181.4 \times 10^6}{217(550-50)}$$

$$= 1671.88 \ mm^2$$

$$Ast_2 = \frac{Asc \times FSC}{0.87 \times fy} = \frac{1671.88 \times 217}{0.87 \times 250}$$

$$= 1668.03 \ mm^2$$

$$Ast\,limit = \frac{Mu\,limit}{0.87 fy \ (d - 0.42 \ x_{umax})}$$

$$x_{umax} = 0.53 \times 550$$

$$= 291.5 \ mm$$

$$= \frac{268.6 \times 10^6}{0.87 \times 250 \times (550 - 0.42 \times 291.5)}$$

$$= 2888.28 \ mm^2$$

$$Ast = Ast\,limit + Ast_2$$

$$= 2888.28 + 1668.03 = 4556.31 \ mm^2$$

$Asc = 1671.88$ provide 4 bar 24 dia

$$Asc = 4 \times \frac{\pi}{4} \times 24^2 = 1809 \ mm^2$$

$Ast = 4556.31$ provide 5 bar 35 dia

$$Ast = 5 \times \frac{\pi}{4} \times 35^2 = 4810.56 \ mm^2$$

Step 2

To find x_u

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

$\Rightarrow 0.36 \times 20 \times 300 x_u + 217 \times 1809 = 0.87 \times 250 \times 4810.56$

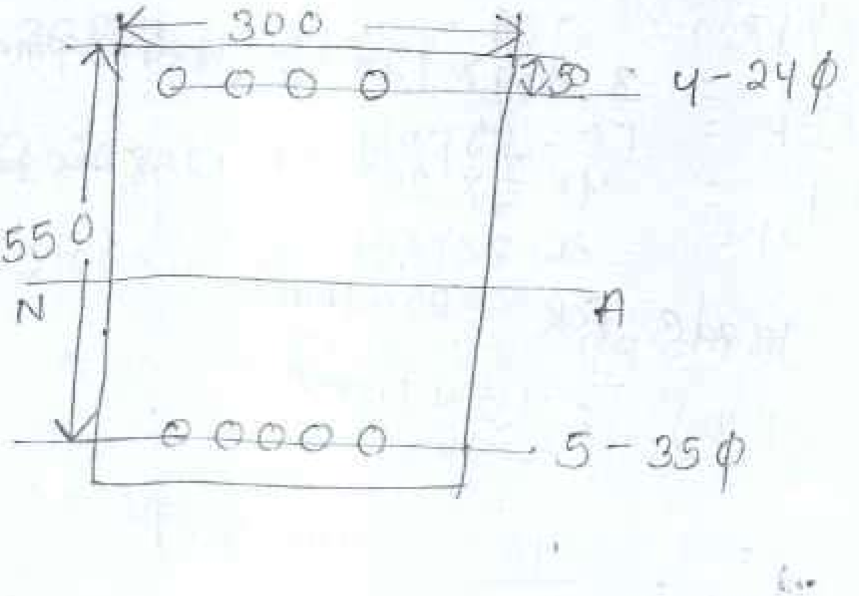
$\Rightarrow 2160 x_u + 392553 = 1046296.8$

$\Rightarrow 2160 x_u = 1046296.8 - 392553$

$\Rightarrow x_u = \dfrac{653743.8}{2160} = 302 \text{ mm}$

$x_{umax} = 291.5 \text{ mm}$

$x_u > x_{umax}$. the beam is over reinforced section.



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2b. A doubly reinforced conc beam having rectangular section 300 mm x 540 mm overall depth is reinforced with 3 bars of 12 mm dia in compression side & 4 bars 20 mm dia at tension side. The effective cover to bars is 40mm. use M20 grade concrete & Hysd reinforced Calculate flexural strength of the section.

Soln

Width of beam (b) = 300mm

Overall depth (D) = 540mm

Effective cover(d') = 40mm

Effective depth(d) = $D - d'$ = 540 - 40

= 500mm

$A_{sc} = 3 \times \frac{\pi}{4} \times 12^2 = 339.29 \, mm^2$

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

M20 grade $f_{ck} = 20 \, N/mm^2$

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

$\frac{d'}{d} = \frac{40}{500} = 0.08 = 0.1$

$f_{sc} = 353 \, N/mm^2$

Step-1

$$A_{st2} = \frac{f_{sc} A_{sc}}{0.87 f_y} = \frac{353 \times 339.29}{0.87 \times 415}$$

$$= 332\, mm^2$$

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

$$= 1256.63 - 332 = 924.63\, mm^2$$

Step-2

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

$$= 0.138 \times 20 \times 300 \times 500^2$$

$$= 207\ kNm$$

$$x_{umax} = 0.48 d = 0.48 \times 500 = 240\, mm$$

To find (x_u)

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

$$= 2160 x_u + 119769.37 = 453706.26$$

$$= 2160 x_u = 453706.26 = 119769.37$$

$$= x_u = \frac{453706.26 - 119769.37}{2160}$$

$$= 154.6\ mm$$

$x_u < x_{umax}$ so the beam is under reinforced section.

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

$= 0.36 \times 20 \times 300 \times 154.6 (500 - 0.42 \times 154.6) +$

$339.29 \times 353 (500 - 40)$

$= 200 \text{ KNm}$

Design of shear

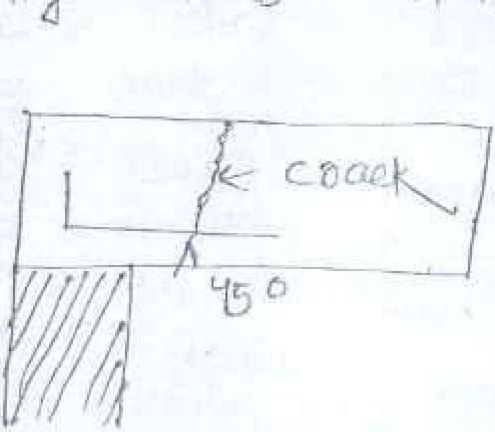
Shear force is present in beams where there is a change in bending moment along the span it is equal to the rate of change of bending moment. So several experimental studies have been conducted to understand the various modes of failure, which ~~of the~~ occure due to possible combination of bending moment acting at a given section of shear &

These modes are as follows :-

① Diagonal tension failure
(ii) Flexural shear failure
(iii) Diagonal compression failure

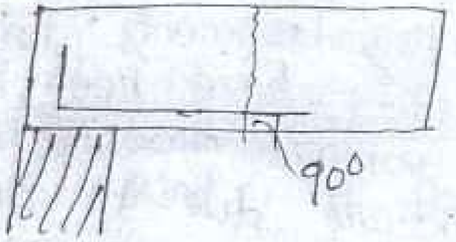
① Diagonal tension failure :-

Diagonal tension failure which occurs under large shear force and less bending moment. Such cracks are normally at 45° with the horizontal.



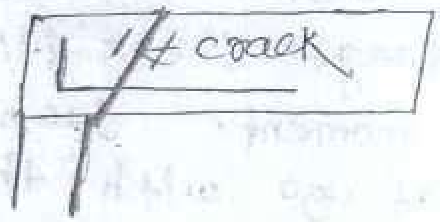
(II) Flexural shear failure

Flexural shear failure which occures under large bending moment & less shear force. Such cracks are normally at 90^0 with the horizontal.



(III) Diagonal Compression failure

Diagonal compression failure which occures under large shear force as shown in fig. Normally it occures in beams which are reinforced against heavy shear.



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Ultimate nominal stress (τv)

For a beam of uniform depth, the ultimate nominal shear stress τv is given by

$$\boxed{\tau v = \frac{Vu}{bd}}$$ (page - 72)

where,

Vu = factored shear force due to load

Shear reinforcement in beam :-

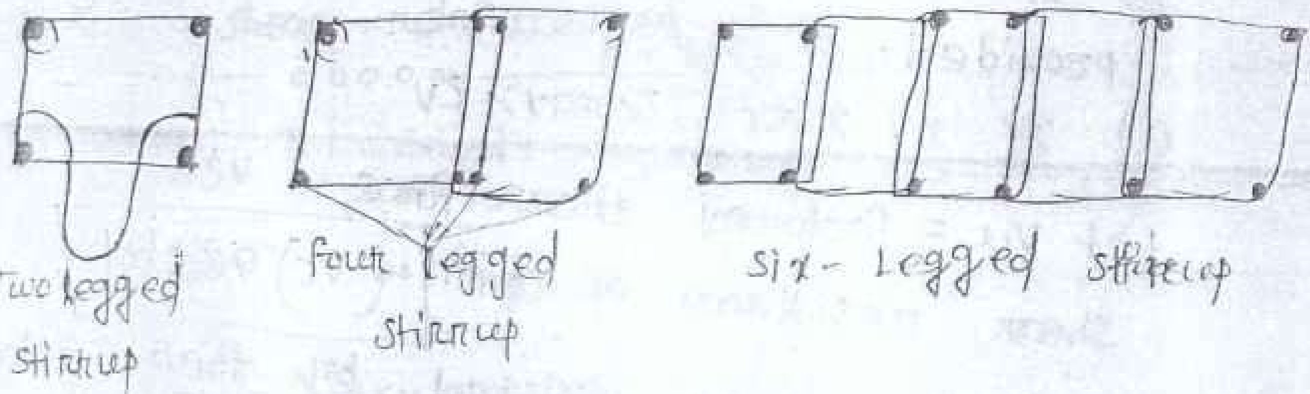
The shear reinforcement is made by any of the following forms.

(i) vertical stirrup

(ii) Inclined stirrup (not less than 45^0)

(iii) Bent up bar along with stirrup

Type of stirrup :-



Bentup reinforcement to resist shear

Bent up bars along with stirrups must be used to resist shear. The shear resistance provided by bent up bars shouldn't be taken more than 50% of the total shear reinforcement required.

Design shear strength of conc. (τc)

(a) Without shear reinforcement The design shear strength 'τc' of conc in beam without shear reinforcement.

(Code book - page no - 73 table no - 19)

(b) With shear reinforcement

under no circumstances with shear reinforcement shall the nominal shear stress in beam exceeds $\tau_{c\,max}$

(page - 73, table no - 20)

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NOTE :-

(i) If $\tau_v < \tau_c$, min^m shear reinforcement provided.

(ii) If $\tau_v > \tau_c$, $\tau_{c\,max} > \tau_v$

Let V_u = factored shear force

Shear resistance of conc. $\boxed{(V_c) = \tau_c bd}$

Net shear to be resisted by shear reinforcement = $\boxed{V_{us} = V_u - V_c}$

The strength of shear reinforcement V_{us} shall be calculated.

(i) For vertical stirrup

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

(ii) For inclined stirrup

$$V_{us} = \frac{0.87 f_y A_{sv} d}{S_v} (\sin\alpha + \cos\alpha)$$

(iii) For single bar or singly group of parallel bars, all bent up at the same cross section (c)

$$V_{us} = 0.87 f_y \, A_{sv} \sin\alpha$$

where, A_{sv} = total cross-sectional area of stirrup legs effective.

S_v = stirrup spacing along the length of the member.

α = Agle between inclined stirrup or bent up bar.

Min^m shear reinforcement

$$\frac{A_{sv}}{b s_v} = \frac{0.4}{0.87 f_y}$$

$$\Rightarrow s_v = \frac{A_{sv} \, 0.87 f_y}{0.4 b}$$

Max^m spacing of shear reinforcement

p shalln't be exceed

(i) 300 mm

(ii) 0.75d

1Q A simply supported reinforced concrete beam is 250 mm wide & 500 mm effective depth & is reinforced with 5 bars of 18 mm as tensile steel. If the beam is subjected to factored shear of 62.5 KN at the support. Find the nominal shear stress at the supported & design shear reinforcement use M20 grade concrete & Fe 415 steel.

Solⁿ Given data:-

width of the beam = 250mm

Effective depth = 500 mm

$Ast = 5 \times \frac{\pi}{4} \times 18^2 = 1272.34\ mm^2$

Factored shear $V_u = 62.5\ KN$

M20 grade $f_{ck} = 20\ N/mm^2$

Fe415 $f_y = 415\ N/mm^2$

Step-1

Nominal shear stress $(\tau_v) = \frac{V_u}{bd}$

$$= \frac{62.5 \times 10^3}{250 \times 500} = 0.5\ N/mm^2$$

Step-2 % of steel $= \frac{1272.34}{250 \times 500} \times 100 = 1\%$

Step-III

For 1% steel, $\tau_c = 0.62\ N/mm^2$

$\tau_v < \tau_c$ so minimum shear reinforcement is provided.

Provide 6mm ϕ mild steel bars for stirrup of 2 legged stirrup.

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

$$= \frac{0.87 \times 250 \times \left(2 \times \frac{\pi}{4} \times 6^2\right)}{0.4 \times 250}$$

$= 123 \cdot 688$ mm

Sv shall not be exceed

(i) 300 m·m

(ii) $0.75d = 0.75 \times 500 = 375$ mm

provide two legged 6mm ϕ stirrup

(a) 123 mm c/c.