Question No 3: Explain the mechanics of RC beams under the gravity load.

ANSWER:

1. Uncracked Concrete - Elastic stage:

As loads much lower then the ultimate, Concrete remains uncracked in compression as well as tension and the behaviour of steel and concrete both is elastic.

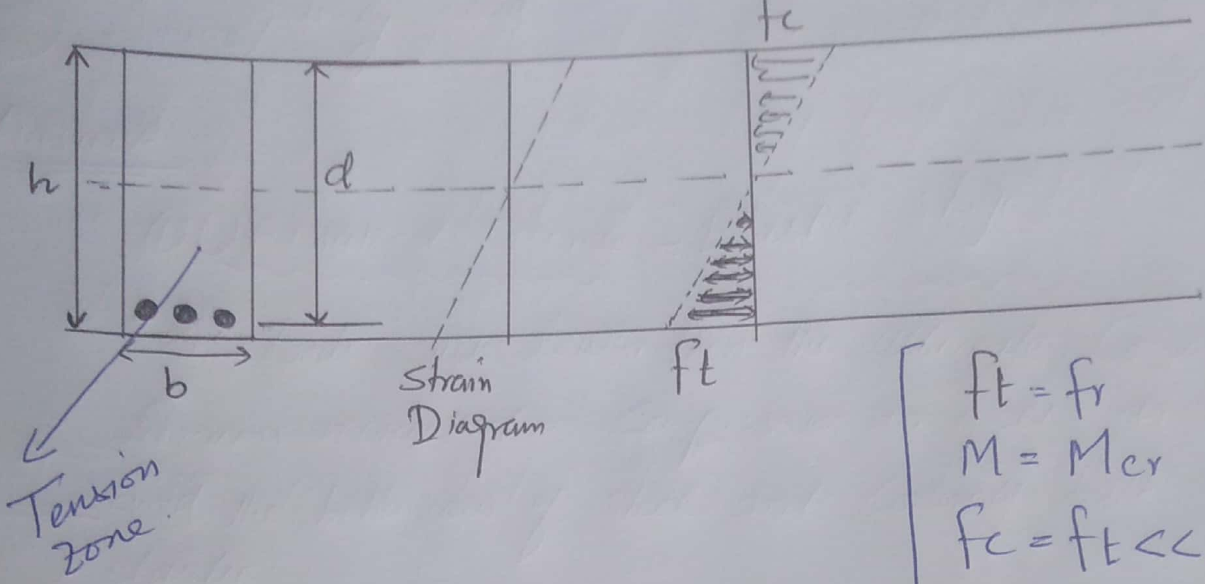
2. Cracked Concrete (Tension zone) - Elastic stage):

With increase in load, Concrete crack in tension but remains uncracked in compression. Concrete in compression and steel in tension both behave in elastic manner.

3. Cracked Concrete (Tension zone) Inelastic (ultimate strength) stage:

Concrete is cracked in tension both enters in to inelastic range. At collapse, steel yeilds and Concrete in Compression Crushes.

Stage 1: Behaviour:



$$\left[\begin{array}{l} f_t = f_r \\ M = M_{cr} \\ f_c = f_t << f_c' \end{array}\right]$$

Calculaton of forces:

$$C = 0.5 f_c \times (b \times 0.5h)$$

$$T = 0.5 f_t \times (b \times 0.5h).$$

$$C = T \Rightarrow f_c = f_t.$$

$$M = 0.5 f_c \times (b \times 0.5h) \times (2/3\, h)$$

$$= 1/6\, f_c \times b \times h^2$$

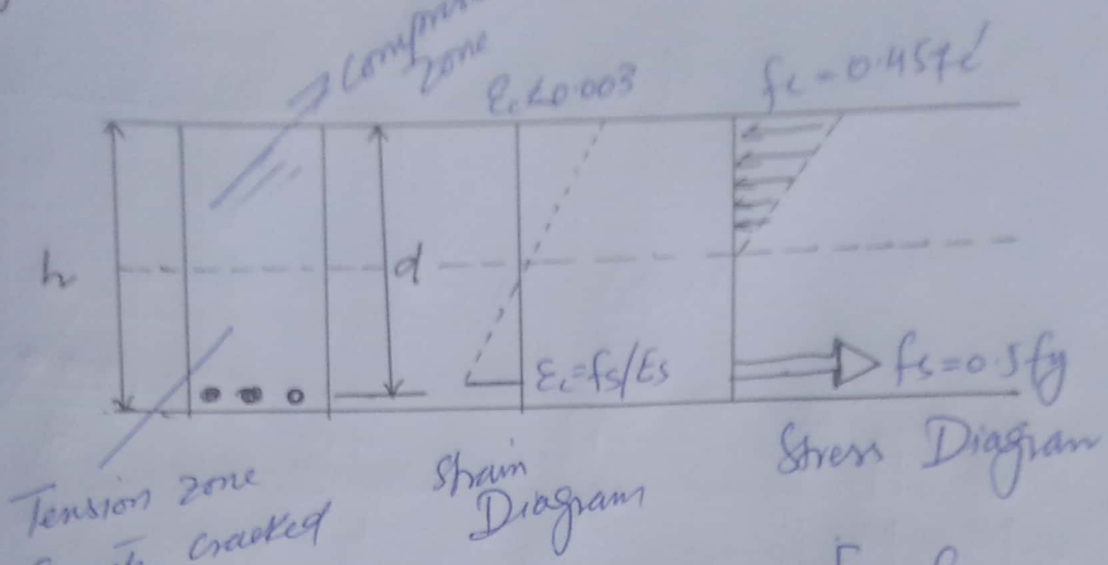
$$f_c = f_t = 6M(bh^2)$$

At $f_t = f_r$, where modulus of rupture $f_r = 7.5\sqrt{f_c'}$

Cracking moment capacity, $M_c = f_r \times I_g/(0.5h)$

$$= (f_r \times b \times h^2)/6.$$

Stage 2. Behaviours:



$f_t > f_r$

$M > M_{cr}$

$f_c = 0.45 f_c'$

$f_s = 0.5 f_y'$.

Calculation of forces:

In terms of moment Couple ($\Sigma M = 0$).

$M = T/a = A_s f_s (d - c/3)$

$A_s = M / f_s (d - c/3)$

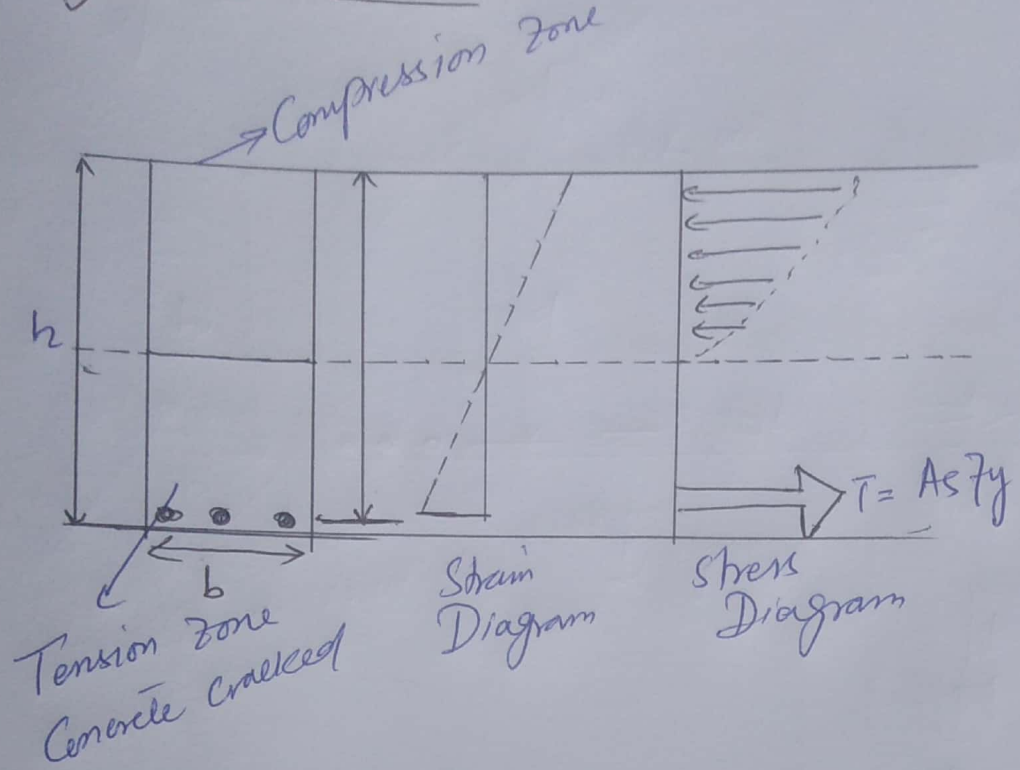
$C = T$ ($\Sigma F_x = 0$).

$\left(\frac{1}{2}\right) f_c b c = A_s f_s$

$C = 2 A_s f_s / f_c b$

$C = 2 A_s n / b$.

Stage 3 Behaviour.



Calculation:

In terms of moment of couple ($\Sigma M = 0$)

$M = T/a = A_s f_y (d - a/2)$. $C = T$ ($\Sigma F_x = 0$)

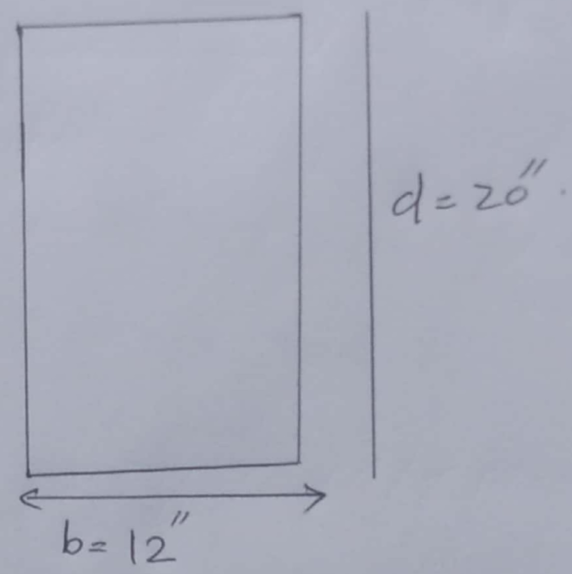
$A_s = M / f_y (d - a/2)$

$0.85 f_c' a b = A_s f_y$

$a = A_s f_y / 0.85 f_c' b$.

Question No 2:

Design a doubly reinforced concrete beam for an ultimate flexural demand of 3500 In-kips. The beam sectional dimension are restricted. Material strength are $f'_c = 3ksi$ and $f_y = 40 ksi$



Solution:

Step No 1: Calculation of ϕM_{nmax} (singly)

$\rho_{max}(singly) = 0.0203$

$A_{smax}(singly) = \rho_{max}(singly)^{bd} = 4.87\ in^2$

$\phi M_{nmax}(singly) = 2948.88\ In\text{-}kips$

Step No 2:

Moment to be Carried ~~by~~ Compression steel:

$M_u(extra) = M_u - \phi M_{n\,max}$ (Singly)

$= 3500 - 2948.88 = 551.12$ In-kip

Step No 3: Find ε_s and f_s:

From table 2 $d = 20'' > 12.3''$ and for $d' = 2.5''$

d'/d is $0.125 < 0.20$ for grade 40 steel. So, Compression steel will yield.

Stress in Compression steel $f_s = f_y$.

Alternatively.

$\varepsilon_s' = (0.003 - 0.008\, d'/d)$ — (1)

$\varepsilon_s' = (0.003 - 0.008 \times 2.5/20) = 0.002 > \varepsilon_y = 40/29000$

$= \underline{\underline{0.00137}}$

As

ε_s is greater then ε_y, So, Compression steel will yeild.

Step No4:

Calculation of A_s' and A_{st}.

$A_s' = M_u(extra) / \{f_s'(d-d')\} = 551.12 / \{(0.90 \times 40 \times (20-2.5)\}$.

$= 0.8747 \; in^2$.

Total amount of tension reinforcement (A_{st}) is

$A_{st} = A_{s\,max}$ (singly) $= 4.87 + 0.8747 = 5.744 \; in^2$

Using # 8 bars with bar area $A_b = 0.79 \; in^2$.

No. of bars to be provided on tension side $= A_{st}/A_b =$

$= 5.744 / 0.79$

$= 7.27$

No. of bars to be provided on Compression side $= A_s'/A_b$

$= 0.8747 / 0.79$

$= 1.107$

Step No5:

Ensure that $d'/d < 0.2$ (for grade) 40. So that. Selection of bars does not create compressive stresses lower than yield.

with tensile reinforcement of 10 # 8 bars in 3 layers
Compression reinforcement of 4 # 8 bars in single layer
$d = 18.625''$ and $d' = 2.375$.

$$d'/d = 2.375/18.625 = 0.12 < 0.20 \Rightarrow OK$$

Step 6: Ductility Requirement: $A_{st} \leq A_{st}\ max$.

A_{st} is the total steel area actually provided as tension reinforcement must be less than A_{st} max.

$$A_{st\,max} = A_{s\,max}(singly) + A_s' f_s'/f_y \doteq 3.16\,in^2.$$

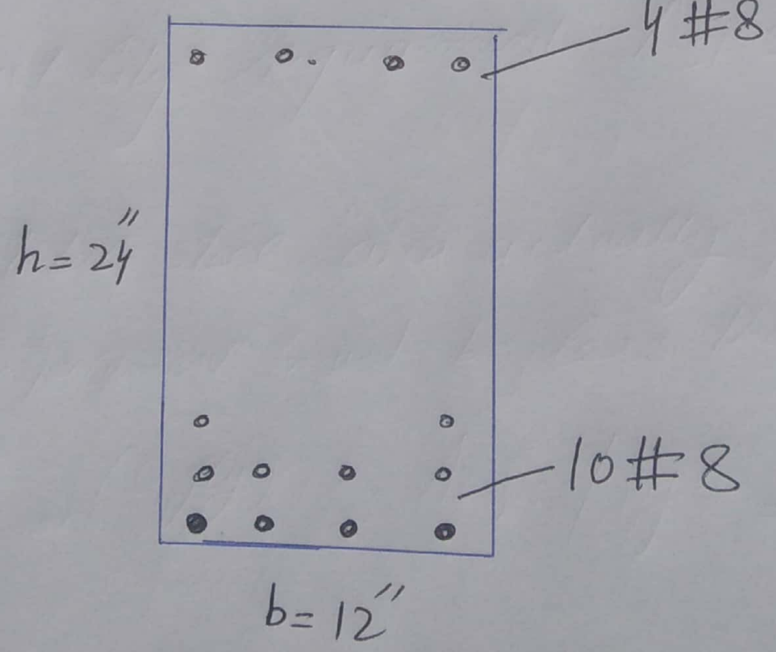
$$A_{s\,max}(singly) = 4.87 + 3.16 = 8.036\,in^2.$$

$$A_{st} = 7.9\,in^2.$$

$A_{st} = 7.9\ in^2 < A_{st\,max}$ ok.

Step 7: Drafting:

Provide 10 # 8 bar (7.9 in^2 in 3 layer) on Tension side 4 # 8 (3.16 in in 1 layer) on Compression side

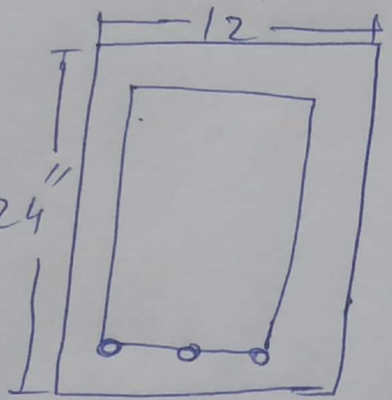


Question No 2:

Sol: $h_{max} = \frac{L}{16}$

$$= \frac{30 \times 12}{16} = 22.5'' =$$

let $h = h/2 = \frac{24}{2} = 12''$



d = effective depth.

$d = h - c.c - \phi - 1/2\ \phi$ main steel.

$d = 24 - 1.5 - \frac{3''}{8} - \frac{1}{2}(1)$

$d = 21.5''$

Beam self load = 150 lb/ft³ $\left(\frac{17}{12} \times \frac{24}{12}\right)$

= 300 lb/ft

P_u = 1.2 DL + 1.6 L.L

= 1.2 (1000 + 300) + 1.6 (1100)

P_u = 3320 lb/ft

$M = \frac{wl^2}{8} = \frac{3320(30)^2}{8}$ = 373500 lb/ft

= 448200 lb/in

= 4482 K-In.

Trail I:

$A_s = \frac{M_u}{0.9 \times f_y (d - a/2)} \rightarrow a = \frac{A_s f_y}{0.85 f'_c b}$

A_s man

a = 0.2d

a = (0.2)(21.5)

a = 4.3" say 5"

$$A_s = \frac{4482}{0.9 \times 60(21.5 - 5/2)}$$

$A_s = 4.36 in^2$

$$a = \frac{A_s f_y}{0.85 f'_c b}$$

$$a = \frac{(4.36)(60)}{(0.85)(4)(12)}$$

$a = 6.41''$

$$A = \frac{4482}{(0.9)(60)(21.5 - \frac{6.41}{2})}$$

$A = 4.53$

Trail # 2

$A_s = 4.57 in^2$

Find No of bar=

No. of bar= $\frac{\text{T. area of steel}}{\text{Area of one bar}}$.

$= \frac{4.57 in}{\frac{\pi}{4}(5/8)^2}$

= 15 Bar.

For 5 # Bar = $\frac{4.57}{\frac{\pi}{4}(5/8)^2}$

= 6 Bar

Ductility sketch.