# Singly (WSD)

## Design step:

1. Assume,

depth, h = $\square$

width, b = $\square$

2. Total load calculation:

$TL = D.L + L.L$

N.B: including to its own weight থাকলে self weight যোগ করতে হবে না,
in addition/super imposed থাকলে self weight = $\left(\frac{bh}{144} \times 150\right)$ plf যোগ করতে হবে। meter দেওয়া থাকলে = $(bh \times 24)$ - KN/m

3. Maximum moment calculation:

[From BMD Diagram / Moment capacity দেওয়া থাকলে]

4. depth check

$$n = \frac{E_s}{E_c} = \frac{29 \times 10^9}{57000\sqrt{f_c'}}$$

$$r = \frac{f_s}{f_c} = \frac{0.4 f_y}{0.45 f_c'}$$

$$K = \frac{n}{n+r} \; ; \; j = 1 - \frac{K}{3}$$

$$R = \frac{1}{2} f_c j K$$

$$\boxed{d_{req} = \sqrt{\frac{M}{Rb}}}$$

Total depth required, $h_{req}$

$$= (d_{req} + 2.5)$$

2.5 → clear cover

if $h_{req}$ < Assumed depth, h = $\square$

It is singly reinforce beam

[Design ok]

5. Steel area calculation:

$$A_{st} = \frac{M}{f_s j d}$$

d → Assume, effective depth

[N.B: BMD -তে যদি positive and negative Moment দুইটাই থাকে, তাহলে $A_{st}$ দুইটা বের করতে হবে]

For tension,

$$A_{st} = \frac{M_{max}(+ve)}{f_s j d}$$

For compression

$$A_{st} = \frac{M_{max}(-ve)}{f_s j d}$$

## Analysis step:

1. $\rho = \frac{A_s}{bd}$

2. $n = \frac{E_s}{E_c}$

3. $K = \sqrt{(\rho n)^2 + 2\rho n} - \rho n$

4. $j = 1 - \frac{K}{3}$

5. $M_c = \frac{1}{2} f_c K j b d^2$

$M_s = A_s f_s j d$

[N.B: $M_c$ এবং $M_s$ এর মধ্যে যেইটা minimum সেইটাই Allowable moment capacity]

# Singly (USD)

## Design step:

1. **Load calculation:**

$$W_u = 1.2D.L + 1.6L.L$$

2. **Moment calculation:** $M_u = \frac{W_u L^2}{8}$ ← for simply supported

$M_u = \frac{W_u L^2}{2}$ ← for cantilever beam

3. **Depth:**

$$M_u = \phi \rho b d^2 f_y \left(1 - \frac{\beta}{\alpha} \frac{\rho f_y}{f_c'}\right)$$

$\Rightarrow d_{req} = \boxed{\phantom{xx}}$

Here,

$\phi = 0.9$ (for design)

$\rho = 0.85 \beta_1 \frac{f_c'}{f_y} \times \frac{\epsilon_u}{\epsilon_u + \epsilon_y}$

$\frac{\beta}{\alpha} = 0.59$

$\beta_1 = 0.85$ ($f_c' = 4000$ psi)

$\beta_1 = 0.80$ ($f_c' = 3000$ psi)

প্রশ্নে থাকলে দাও

$\epsilon_u = 0.003$

$\epsilon_y = 0.005$

Total depth required, $h_{req} = (d_{req} + 2.5)$

4. **Steel area calculation:**

$$A_s = \frac{M_u}{\phi f_y \left(d - \frac{a}{2}\right)}$$

$A_s = \boxed{\phantom{xx}}$

Here

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

$\boxed{a = \boxed{\phantom{xx}} \times A_s}$

## Analysis step

1. $A_s = \boxed{\phantom{xx}}$ ← ($\square$ # $\square$ bar)

2. $\rho = \frac{A_s}{bd}$

3. $\rho_b = 0.85 \beta_1 \frac{f_c'}{f_y} \times \frac{\epsilon_u}{\epsilon_u + \epsilon_y}$ ($\epsilon_u = 0.002$)

$\beta_1 = 0.85$ ($f_c' \leq 4000$)

$\beta_1 = 0.80$ ($f_c' = 5000$)

4. **Moment calculation**

If, $\rho < \rho_b$ it is under reinforced beam. (tension steel yield at failure)

$$\boxed{M_n = A_s f_y \left(d - \frac{a}{2}\right)}$$

Here,

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

$$\boxed{M_u = \phi M_n}$$

$\phi = 0.483 + 83.3\epsilon_t$

Here,

$\epsilon_t = \epsilon_u \times \left(\frac{d-c}{c}\right)$

$c = \frac{a}{\beta_1}$

[N.B = $\epsilon_t$ এর মান 0.005 এর বেশি আসলে 0.005 নিতে হবে]

If $\rho > \rho_b$ it is over reinforced beam (concrete yield at failure)

$M_n = A_s f_s \left(d - \frac{a}{2}\right)$

যেহেতু এই condition এ $f_s \neq f_y$

Here,

$f_s = E_s \epsilon_u \left(\frac{d-c}{c}\right)$

Here,

$E_s = 29 \times 10^9$

$\epsilon_u = 0.003$

$\boxed{c = \frac{a}{\beta_1}}$

At equilibrium

$C = T$

$0.85 f_c' \beta_1 c b = A_s f_s$

$\Rightarrow c = \boxed{\phantom{xx}}$

$c = \frac{a}{\beta_1} \Rightarrow a = \boxed{\phantom{xx}}$

$f_s = \boxed{\phantom{xx}}$

যদি, $f_s > f_y$

$M_n = A_s f_y \left(d - \frac{a}{2}\right)$

$M_n = \boxed{\phantom{xx}}$

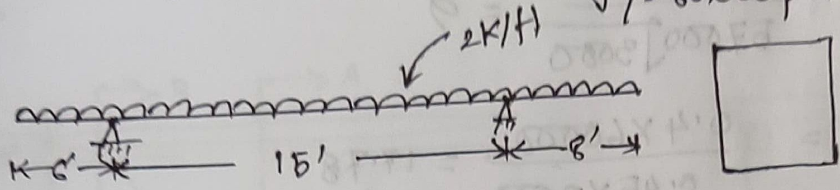
$$\boxed{M_u = \phi M_n}$$

# Singly Reinforce Beam (WSD)

*Design*

* $f_s$ / $f_y$ দেওয়া থাকলে দুইটার যেকোন একটি method এ করা যাবে।
* But $f_s$ দেওয়া থাকলে USD তে করা যাবে না, কারণ USD তে $f_y$ দরকার

**# Problem:** Design the beam when $f_c' = 3000$ psi, $f_y = 60{,}000$ psi

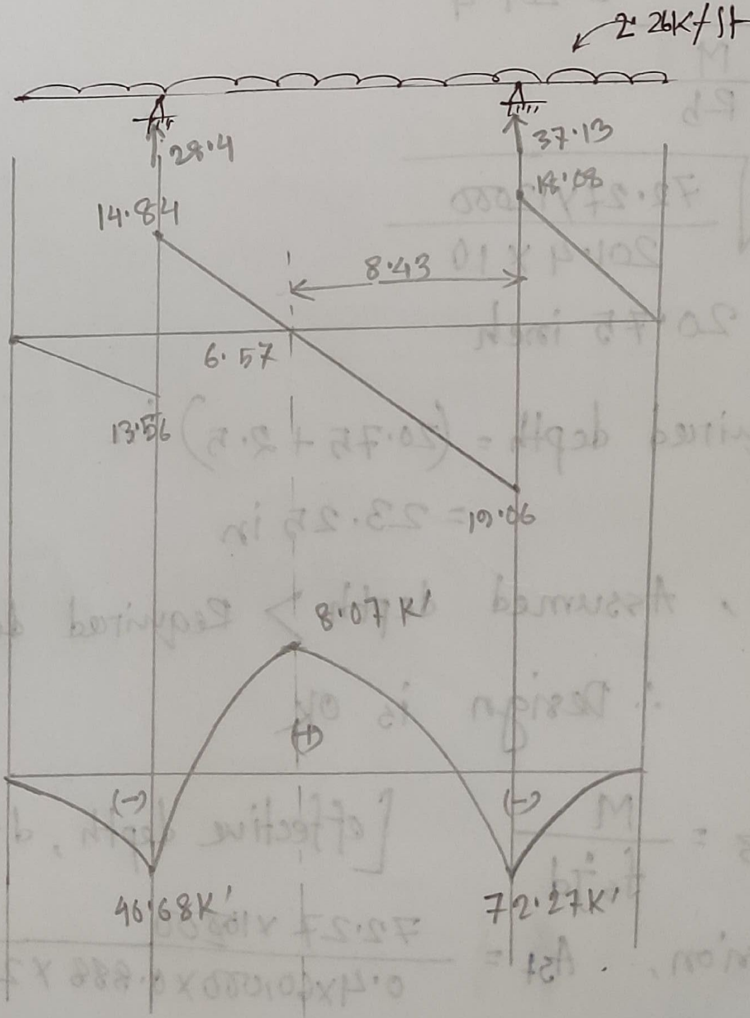



**Solution:**

**Step-01** Assume the depth = 25 inch
Assume the width = 10 inch

**Step-02** Dead load $= \left(\frac{25 \times 10}{144} \times 150\right)$ plf $= 260.41$ plf

$\therefore$ Total load $= (260.41 + 2000)$ plf $= 2260.41$ plf $= 2.26$ k/ft



Step-03

depth check

$\therefore n = \frac{E_s}{E_c} = \frac{29 \times 10^6}{57000\sqrt{3000}} = 9$

$\therefore r = \frac{f_s}{f_c} = \frac{0.4 \times 60000}{0.45 \times 3000} = 17.78$

$\therefore K = \frac{n}{n+r} = \frac{9}{9+17.78} = 0.336$

$j = 1 - \frac{K}{3} = \left(1 - \frac{0.336}{3}\right) = 0.888$

$R = \frac{1}{2} f_c j K = \frac{1}{2}(0.45 \times 3000) \times 0.888 \times 0.336$

$= 201.4$

$\therefore d = \sqrt{\frac{M}{Rb}}$

$= \sqrt{\frac{72.27 \times 12000}{201.4 \times 10}}$

$= 20.75$ inch

$\therefore$ Required depth $= (20.75 + 2.5)$ in

$= 23.25$ in

Hence, Assumed depth > Required depth

$\therefore$ Design is ok

Step-04

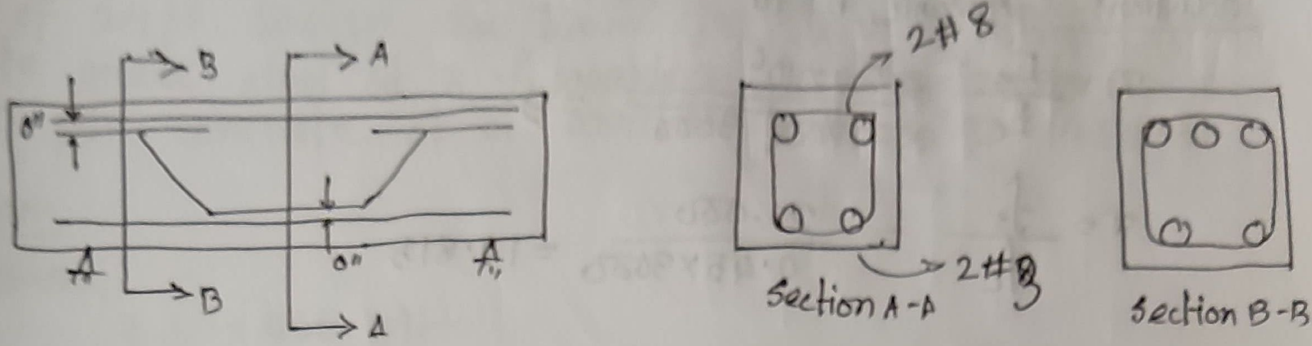
Now, $A_s = \frac{M}{f_s j d}$ [effective depth, $d = (25 - 2.5)$
$= 22.5$ in

for compression, $A_{st} = \frac{72.27 \times 12000}{0.4 \times 60{,}000 \times 0.888 \times 20.75}$

$= 1.81$ in$^2$ $\approx$ 3#8

For tension,

$$A_s = \frac{8.04 \times 12000}{0.4 \times 60,000 \times 0.888 \times 22.5} = 0.20 \text{ in}^2 \quad 2\#3$$



Design

Problem 02: Determine the dimension and reinforcement of a rectangular beam of moment capacity 100 K-ft ($f_s = 20{,}000$ psi, $f_c' = 3000$ psi)

Solution: Assume $b = 10$

$$n = \frac{E_s}{E_c} = \frac{29 \times 10^6}{57000\sqrt{3000}} = 9$$

$$r = \frac{f_s}{f_c} = \frac{20{,}000}{0.45 \times 3000} = 14.815$$

$$K = \frac{n}{n+r} = \frac{9}{9+14.815} = 0.378$$

$$J = 1 - \frac{K}{3} = 0.874$$

$$R = \frac{1}{2} f_c jK = \frac{1}{2} \times (0.45 \times 3000) \times 0.874 \times 0.378$$

$$= 222.94$$

$$d_{req} = \sqrt{\frac{M}{Rb}} = \sqrt{\frac{100 \times 12000}{222.94 \times 10}} = 23.2 \text{ in}$$

Now,

$$A_{st} = \frac{M}{f_s jd} = \frac{100 \times 12000}{20{,}000 \times 0.874 \times 23.2}$$

$$= 2.96 \text{ in}^2$$

$$= 3 \# 9 \text{ bar}$$ Ans.

Design

Problem-03: A rectangular beam is to carry a uniformly distributed live load of 680 plf and support the dead load of a wall weighing 380 plf in addition to its own weight on a simple span of 24 ft. Design the beam for flexure using intermediate grade steel at a working stress of 20,000 psi and 3000 psi concrete at a working stress of 1350 psi

superimposed self weight

Solution:

Given,

L.L = 680 plf

D.L = 380 plf

$f_s$ = 20,000 psi

$f'_c$ = 3000 psi

$f_c$ = 1350 psi

L = 24 ft

(i) Assume depth, h = 24 in

width, b = 12 in

Total load $= \left(680 + 380 + \frac{24 \times 12}{144} \times 150\right) = 1360$ plf $= 1.36$ klf

(ii) For simply supported beam, $M_{max} = \frac{WL^2}{8} = \frac{1.36 \times 24^2}{8}$

$= 97.92$ k-ft

(iii) Now,

$$n = \frac{E_s}{E_c} = \frac{29 \times 10^6}{57000\sqrt{3000}} = 9$$

$$r = \frac{f_s}{f_c} = \frac{20,000}{1350} = 14.81$$

$$K = \frac{n}{n+r} = \frac{9}{9+14.81} = 0.378$$

$$j = 1 - K/3 = 1 - \frac{0.378}{3} = 0.874$$

$R = \frac{1}{2} f_c j K$

$= \frac{1}{2}(1350 \times 0.874 \times 0.378)$

$= 223$

$\therefore d = \sqrt{\frac{M}{Rb}}$

$= \sqrt{\frac{97.92 \times 1000 \times 12}{223 \times 12}}$

$= 20.95$ in

$\therefore$ Require depth $= (20.95 + 2.5) = 23.45$ in

$\therefore$ Assume depth > require depth

$\therefore$ design ok

(IV)

Now,

effective, $d = (24 - 2.5)$

$= 21.5$

$A_s = \frac{M}{f_s j d}$

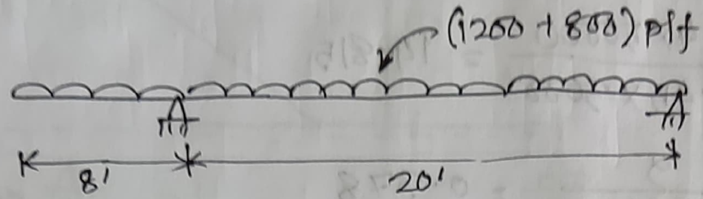
$= \frac{97.92 \times 1000 \times 12}{20,000 \times 0.874 \times \cancel{20.95}\ 21.5}$

$= 3.13$ in$^2$

$= 4\#9$

Design

Problem: Design a over hanging beam in figure to support a live load of 1200 plf and a dead load of 800 plf including a its self weight using $f_c' = 3000$ psi, $f_y = 5000$ psi.

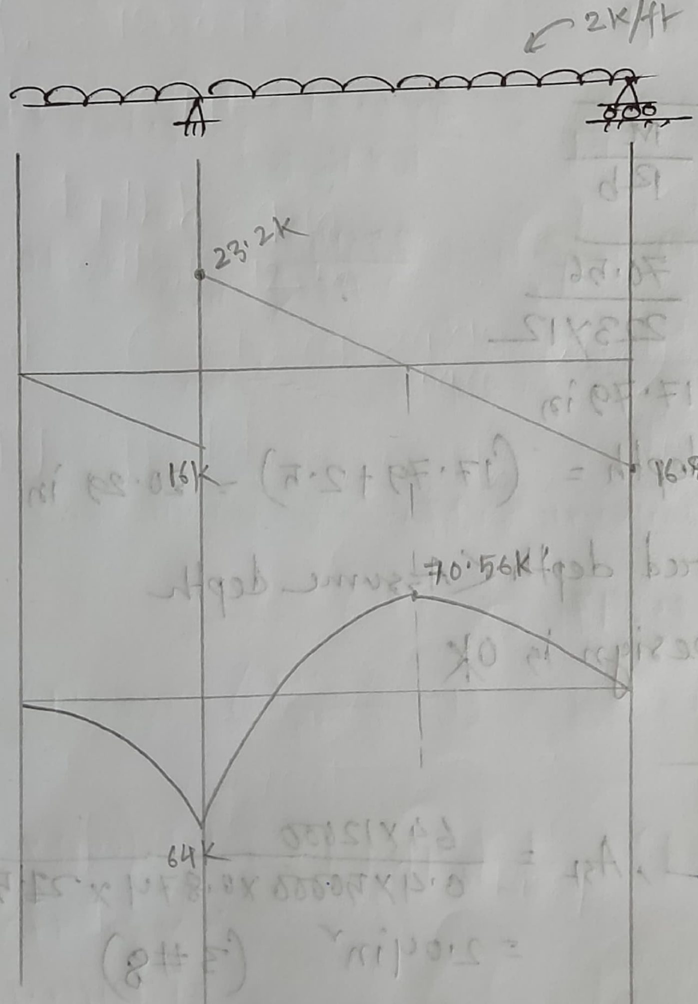



Solution:

Assuming depth, $h = 24$ in

width, $b = 12$ in

Total load = (1200 + 800) plf = 2000 plf = 2 Klf



Now, depth check

$$n = \frac{E_s}{E_c} = \frac{29 \times 10^9}{57000\sqrt{3000}} = 9$$

$$r = \frac{f_s}{f_c} = \frac{0.4 \times 50000}{0.45 \times 3000} = 14.815$$

$$K = \frac{n}{n+r} = \frac{9}{9+14.815} = 0.378$$

$$j = 1 - K/3 = 1 - 0.378/3 = 0.874$$

$$R = \frac{1}{2} f_c j K$$

$$= \frac{1}{2} \times (0.45 \times 3000) \times 0.874 \times 0.378$$

$$= 223$$

$$d_{req} = \sqrt{\frac{M}{Rb}}$$

$$= \sqrt{\frac{70.56}{223 \times 12}}$$

$$= 17.79 \text{ in}$$

required depth $= (17.79 + 2.5) = 20.29$ in

$\therefore$ Required depth < Assume depth

$\therefore$ Design is OK

Now,

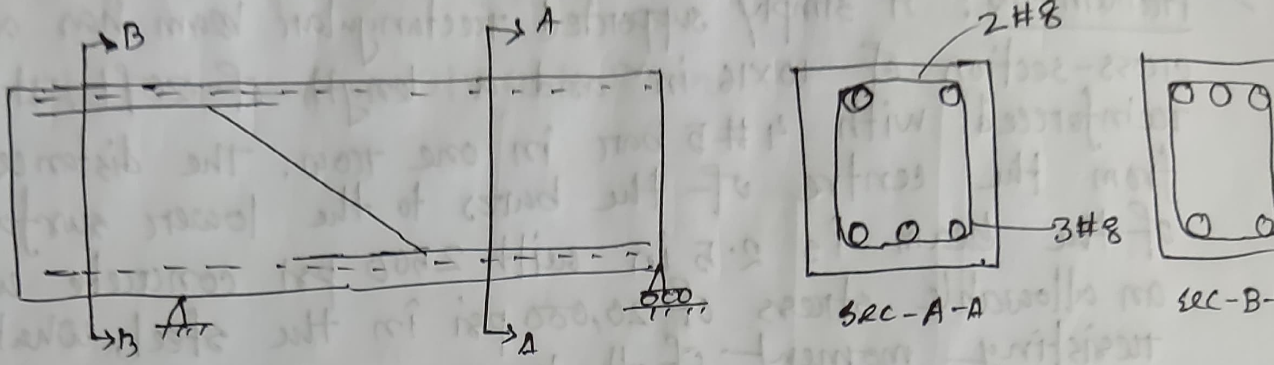
$$A_s = \frac{M}{f_s j d}$$

For compression zone, $A_{st} = \dfrac{64 \times 12000}{0.4 \times 50000 \times 0.874 \times 21.5}$

$= 2.04 \text{ in}^2$ (3 #8)

For tension zone, $A_{st} = \dfrac{70.56 \times 12000}{0.4 \times 5000 \times 0.874 \times 21.5}$

$= 2.31 \text{ in}^2$ (3 #8 bar)


B
A
2#8
3#8
SEC-A-A
SEC-B-

Analysis

Problem-05: A simply supported rectangular beam has a to cross-section of 10X16 $in^2$ and a length of 20ft. It is reinforced with 4 #5 bar in one row. The distance from the centre of the bars to the lower surface of the beam is 2·5 in with 2500 psi concrete and an allowable stress of 20,000 psi in the steel; what is resisting moment of the beam.

Solution:

$b = 10"$ $\qquad f_c' = 2500$

$h = 16"$ $\qquad f_s = 20{,}000$

$d = (16 - 2.5) = 13.5"$

$L = 20ft$

Steel ratio, $\rho = \frac{A_s}{bd} = \frac{4 \times 0.31}{10 \times 13.5} = 9.185 \times 10^{-3}$

$n = \frac{E_s}{E_c} = \frac{29 \times 10^{6}}{57000\sqrt{2500}} = 10.175 \approx 10$

$\therefore k = \sqrt{(\rho n)^2 + 2\rho n} - \rho n$

$= \sqrt{(9.185 \times 10^{-3} \times 10)^2 + 2 \times (9.185 \times 10^{-3} \times 10)} - (9.185 \times 10^{-3}$

$= 0.347$

$j = 1 - k/3 = \left(1 - \frac{0.347}{3}\right) = 0.884$

Now,

$M_c = Rbd^2 = \frac{1}{2} f_c j k b d^2 = \frac{1}{2} \times (0.45 \times 2500) \times 0.88$

$\times 0.347 \times 10 \times 13.5^2$

$= 314464.63$ lb-in

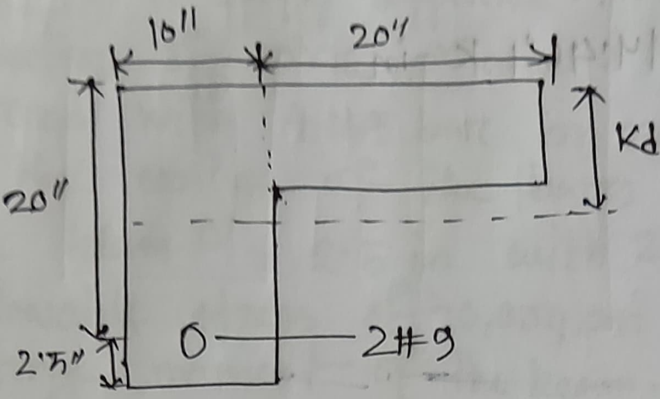
$= 314.464$ k-in

$M_s = A_s f_s jd = (4\times0.31)\times20,000\times0.884\times13.5$
$= 295.96$ k-in

Allowable moment 314.464 k-in

Analysis

**Problem-06:** Determine the moment capacity of the bea[m]




$$n = \frac{E_s}{E_c} = \frac{29\times10^6}{57000\sqrt{3000}} = 9$$

**Solution:**

$$Q_c = 10\times Kd\times\frac{Kd}{2} + 20\times4\times\left(Kd-\frac{4}{2}\right) = 5(Kd)^2 + 80Kd - 1[60]$$

$$Q_T = nA_s(d-Kd) = \frac{E_s}{E_c}\times(2\times1)\times(d-Kd)$$

$$= 9\times2\times(d-Kd) = 18d - 18Kd$$

Now, $Q_c = Q_T$

$$5(Kd)^2 + 80Kd - 160 = 18d - 18Kd$$

$$\Rightarrow 5(Kd)^2 + 98Kd - 520 = 0$$

$$\Rightarrow Kd = 4.34$$

$$K = \frac{4.34}{20} = 0.217$$

$$J = 1 - K/3 = \left(1 - \frac{0.217}{3}\right) = 0.928$$

rectangular

Neutra[l] section

$$M_c = \frac{1}{2}f_c JKbd^2 = \frac{1}{2}\times(0.45\times3000)\times0.928\times0.217\times10$$

$$= 543715.2 \text{ lb in.}$$

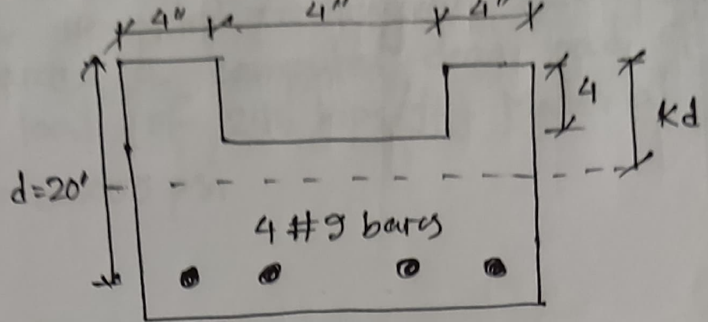
$$= 543.72 \text{ K-in} \quad \text{Ans.}$$

$$M_s = A_s f_s jd = 2\times(0.4\times60{,}000)\times0.928\times20$$

$$= 890.88 \text{ K-in}$$

Analysis

Problem-07 : Calculate the working moment capacity of the section given below. Assume, $f_c' = 3000$ psi & $f_y = 60$ ksi




$$Q_c = 12 \times Kd \times \frac{Kd}{2} - (4\times4) \times (Kd - 4/2)$$
$$= 6(Kd)^2 - 16(Kd - 2)$$

$$n = \frac{E_s}{E_c} = \frac{29\times10^9}{57000\sqrt{3000}} = 9$$

$$Q_T = nA_{st}(d - Kd)$$
$$= 9 \times (4\times1) \times (20 - Kd)$$

At equilibrium

$$Q_c = Q_T$$
$$6(Kd)^2 - 16Kd + 32 = 720 - 36Kd$$
$$\Rightarrow 6(Kd)^2 + 20Kd - 688 = 0$$
$$\Rightarrow Kd = 9.17$$
$$K = \frac{9.17}{20} = 0.485$$
$$J = (1 - K/3) = 0.847$$

$$M_c = \frac{1}{2} f_c jkbd^2 = \frac{1}{2} \times (0.45\times3000) \times 0.847 \times 0.485 \times 2$$
$$= 1258.25 \text{ k-in}$$

$$M_s = A_s f_s jd = 4 \times (60{,}000 \times 0.4) \times 0.847 \times 20$$
$$= 1626.24 \text{ ki}$$

$\therefore$ Moment capacity = 1258.25 k-in Ans.

Design

## Singly reinforced Beam (USD)

**Problem-01**

Find the cross section of the concrete and area of steel required for a simply supported rectangular beam with a span of 15 ft that is to carry a computed dead load of 1.27 kips/ft and a service live load of 2.15 kips/ft. Material strength are $f_c' = 4000$ psi and $f_y = 60{,}000$ psi

**Solution:**

$W_u = 1.2 D.L + 1.6 LL$

$= (1.2 * 1.27 + 1.6 * 2.15) = 4.96$ K/ft

$M_u = \frac{W_u L^2}{8} = \frac{4.96 \times (15)^2}{8} = 139.5$ kft

Now,

$M_u = \varphi \rho b d^2 f_y \left(1 - \frac{\beta}{\alpha} \frac{\rho f_y}{f_c'}\right)$

$139.5 \times 12000 = 0.9 \times 0.018 \times 10 \times d^2 \times \left(1 - 0.59 \frac{0.018 \times 60{,}000}{4000}\right)$

$d^2 = 204.85$

$d = 14.31$ in

required total depth, $h = (14.31 + 2.5)$

$\cong 17$ in

$\rho = 0.85 \beta_1 \frac{f_c'}{f_y} \times \frac{\epsilon_u}{\epsilon_u + \epsilon_y}$

$\rho = 0.85 \times 0.85 \times \frac{4000}{60{,}000} \times \frac{0.003}{0.003 + 00}$

$= 0.018$

$\beta/\alpha = 0.59$

Now,

$A_s = \frac{M_u}{\varphi f_y (d - a/2)}$

$A_s = \frac{139.5 \times 12000}{0.9 \times 60{,}000 \left(14.31 - \frac{1.7647 A_s}{2}\right)}$

$A_s = 2.16$ inch $(3 \# 9)$

Ans.

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

$= \frac{60{,}000 A_s}{0.85 \times 4000 \times 10}$

$= 1.7647 A_s$

Analysis

Problem-02: A rectangular beam has width 12 in and eff depth 17.5 in. It is reinforce with 4#9 bar in one row $f_y = 60,000$ psi and $f_c' = 4000$ psi, what is the normal strength and what is the maximum moment that can utilized in design. according to ACI code.

Solution:

$$\rho = \frac{A_s}{bd} = \frac{4\times 1}{12\times 17.5} = 0.019$$

$$\rho_b = 0.85\beta_1 \frac{f_c'}{f_y} \times \frac{\epsilon_u}{\epsilon_u + \epsilon_y}$$

$$= 0.85\times 0.85\times \frac{4000}{60,000} \times \frac{0.003}{0.003+0.002}$$

$$= 0.0289$$

$\rho < \rho_b$, It is under reinforced beam

Now,

$$M_n = A_s f_y \left(d - \frac{a}{2}\right)$$

$$= 4\times 60,000\left(17.5 - \frac{5.88}{2}\right)$$

$$= 3494400 \text{ lb-in}$$

$$a = \frac{A_s f_y}{0.85 f_c' b} = \frac{4\times 60,000}{0.85\times 4000\times 12} = 5.88$$

So, $M_u = \phi M_n$

$$= 0.87\times 3494400$$

$$= 3040128 \text{ lb-in}$$

Ans.

$$\phi = 0.483 + 83.3\,\epsilon_t$$

$$\epsilon_t = \epsilon_u\left(\frac{d-c}{c}\right)$$

$$= 0.003\times \frac{17.5 - \frac{a}{\beta_1}}{\frac{a}{\beta_1}}$$

$$= 0.003\times \frac{17.5 - \frac{5.88}{0.85}}{\frac{5.88}{0.85}}$$

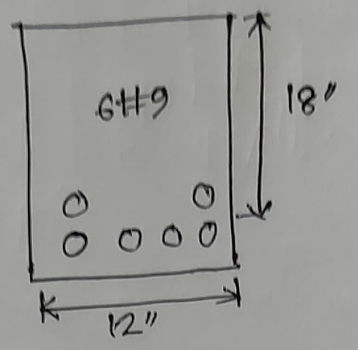
$$\epsilon_t = 0.0046$$

$$\phi = 0.483 + 83.3\times 0.0046$$

$$= 0.87$$

Analysis

Problem: 03 A beam section is shown in figure below. Calculate nominal and ultimate moment.



$f_c' = 3$ ksi

$f_y = 60$ ksi

Solution:

$$\rho = \frac{A_s}{bd} = \frac{(6\times1)}{12\times18} = 0.0278$$

$$\rho_b = 0.85\beta_1 \frac{f_c'}{f_y}\frac{\epsilon_u}{\epsilon_u+\epsilon_y}$$

$$= 0.85\times0.85\times\frac{3}{60}\times\frac{0.003}{0.003+0.002}$$

$$= 0.0217$$

$\rho > \rho_b$. So it is over reinforced beam.

We know,

$$M_n = A_s f_s\left(d-\frac{a}{2}\right)$$

$$= 6\times49649.21\times\left(18-\frac{9.74}{2}\right)$$

$$= 3911364.761 \text{ lb-in}$$

Ans.

$$f_s = E_s\epsilon_u\left(\frac{d-c}{c}\right)$$

$$c = \frac{a}{\beta_1}$$

At equlibrium

$$0.85\times f_c'\beta_1 cb = A_s f_s$$

$$0.85\times3000\times0.85\times c\times12 = 6\times f_s$$

$$24480c = 6\times29\times10^6\times0.003\frac{18-c}{c}$$

$$c^2 = 21.32353(18-c)$$

$$c = 11.46$$

$$a = c\beta_1 = 11.46\times0.85 = 9.74$$

$$\therefore f_s = 29\times10^6\times0.003\times\left(\frac{18-11.46}{11.46}\right)$$

$$= 49649.21 \text{ psi}$$

$$M_u = \phi M_n$$

$$\phi = 0.483+83.3\epsilon_t$$

$$\epsilon_t = \epsilon_u\times\left(\frac{d-c}{c}\right)$$

$$= 0.003\times\left(\frac{18-11.46}{11.46}\right)$$

$$= 0.0017$$

$$\therefore \phi = 0.483+83.3\times0.0017$$

$$= 0.625$$

$M_u = 2444602.97$ lb-in Ans.

# Design of slab

## USD Method

### 1. Thickness of slab

60 grade steel:

- simply supported → $t = \frac{l}{20}$ ft [$l$ = clear span]
- one end continuous → $t = \frac{l}{24}$ ft
- Both end continuous → $t = \frac{l}{28}$ ft
- Cantilever → $t = \frac{l}{10}$

for other grade → $t = \left(0.4 + \frac{f_y}{100}\right) \times \frac{l}{\square} = \square\, l$

### 2. Load calculation:

- $T.L = 1.2\,D.L + 1.6\,L.L$

$D.L = \left(\frac{t}{12} \times 150\right)$ psf — square feet এর calculation হবে।

→ self weight

### 3. Moment calculation:

[From BMD diagram]

### 4. Depth check

- $M_u = \phi \rho b d^2 f_y \left(1 - \frac{\beta}{\alpha} \frac{\rho f_y}{f_c'}\right)$

Here

$\phi = 0.9$ (for design)

$\beta/\alpha = 0.59$

$\rho = 0.85 \beta_1 \frac{f_c'}{f_y} \times \frac{\varepsilon_u}{\varepsilon_u + \varepsilon_y}$

$\varepsilon_u = 0.003$

$\varepsilon_y = 0.005$

$\beta_1 = 0.85$ ($f_c' = 4000$ psi)

$\beta_1 = 0.80$ ($f_c' =$ psi)

$d_{req} = \square$

if, $d_{req} <$ effective depth

- effective depth = Assume depth − 1

[Design ok]

### 5. Steel calculation:

- $A_s = \frac{M_u}{\phi f_y \left(d - \frac{a}{2}\right)}$

$= \square$

Here

$a = \frac{A_s f_y}{0.85 \times f_c' b}$

$= \square A$

$b = 12$ as 12" design

[N.B: Positive negetive এবার design এর জন্য বের করতে হবে]

### 6. Distribution reinforcement:

- If $f_y = 60$ ksi; $A_s(min) = 0.0018$ b
- If $f_y < 60$ ksi; $A_s(min) = 0.0020$ b
- If $f_y > 60$ ksi; $A_s(min) = \frac{0.0018 \times 60000}{f_y}$ b

### 7. Shear check

- $V_u = 1.15 \times \frac{WL}{2} - \frac{\omega d}{12}$ (inch)
- $V_{allowable} = 2\phi\sqrt{f_c'}\, bd$ (b = 12, φ = 0.75)

$\therefore V_u < V_{all}$

Hence [Design OK]

### 8. Bond check

$U_{dev} = \frac{V_{max}}{\Sigma_0 \left(d - \frac{a}{2}\right)}$

$U_{all} = \frac{6.7\sqrt{f_c'}}{D}$

$\therefore U_{dev} < U_{all}$

Hence, [Design OK]

$V_{max} = \frac{WL}{2}$

$\Sigma_0 = \cancel{N}\pi D$;

1ft Bar dia

$a = \frac{A_s f_y}{0.85 \times f_c'}$

# WSD Method

## 1. Thickness of slab:

same as USD

## 2. Load calculation

$T.L = D.L. + L.L$

- $\left[\text{self load} = \frac{t}{12} \times 150 \text{ psf}\right]$

## 3. Moment calculation:

[from BMD Diagram]

## 4. Depth check

$n = \frac{E_s}{E_c}$;

$r = \frac{f_s}{f_c}$;

$k = \frac{n}{n+r}$; $j = 1 - k/3$

$R = \frac{1}{2} f_c j k$;

$d = \sqrt{\frac{M}{Rb}}$

$t_{req} = d + c.c + \frac{dia}{2}$ → distribution rod

$c.c \downarrow 0.75$, $\frac{dia}{2} \downarrow 0.25$

effective depth = (A. dep. − 1)

$t_{req}$ < Assume depth

$\boxed{\text{design ok}}$

## 5. Steel area calculation:

$A_s = \frac{M}{f_s j d}$; $f_s = 0.4 f_y$

## 6. Distribution reinforcem

same as USD

## 7. Shear check

$V_\omega = 1.15 \frac{WL}{2} - \frac{Wd}{12}$

$V_{all} = 1.1 \sqrt{f_c'}\, bd$

$\therefore V_\omega < V_{all}$ $\boxed{\text{design}}$

## 8. Bond check

$U_{dev} = \frac{V_{max}}{\Sigma_0 j d}$

$U_{all} = \frac{3.4\sqrt{f_c'}}{D}$

$U_{dev} < U_{all}$

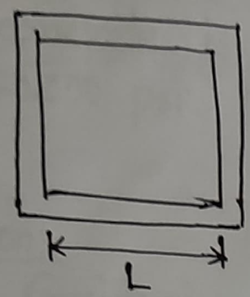
$\boxed{\text{design ok}}$

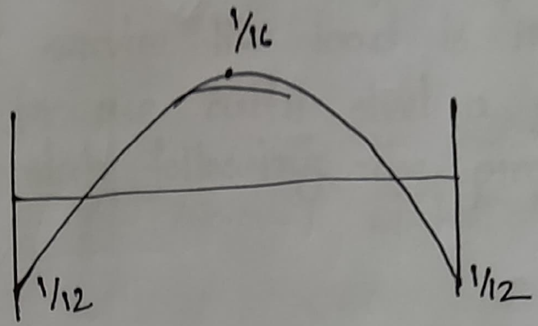
$V_{m}$

$\Sigma_0 =$

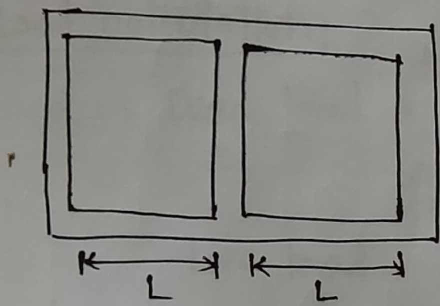
$=$

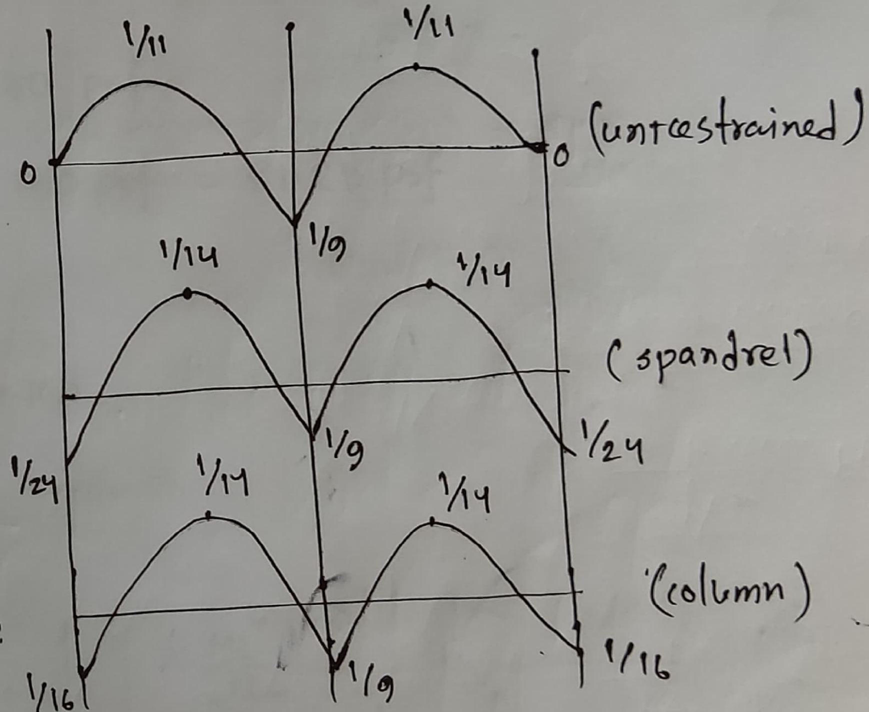
Beam with one span:



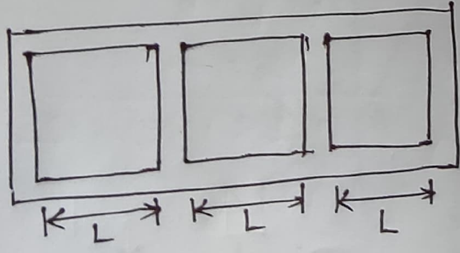



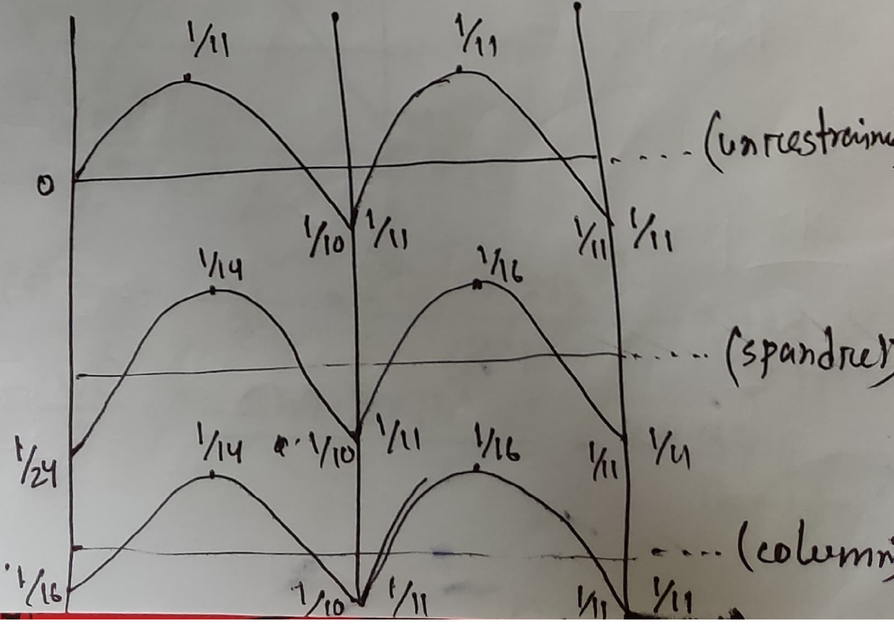

Beam with two spans only:




Beam with more than two span:



USD

Problem-01: A reinforced concrete slab is built integrally with its appurtenance support and consists of two equal spans, each with a clear span of 15 ft. The service live load is 100 psf and 4000 psi concrete is specified for use with steel a yield stress equal to 60,000 psi. Design the slab following the provision of ACI code.

Solution:

Considering the slab is both end continuous,

$$\therefore t = l/28 = \frac{15\times 12}{28} = 6.43 \text{ in} \approx 6.5 \text{ in}$$

Load calculation:

$$\text{Dead load} = \frac{t}{12}\times 150 \text{ psf}$$

$$= \frac{6.5}{12}\times 150 \text{ psf} = 81.25 \text{ psf}$$

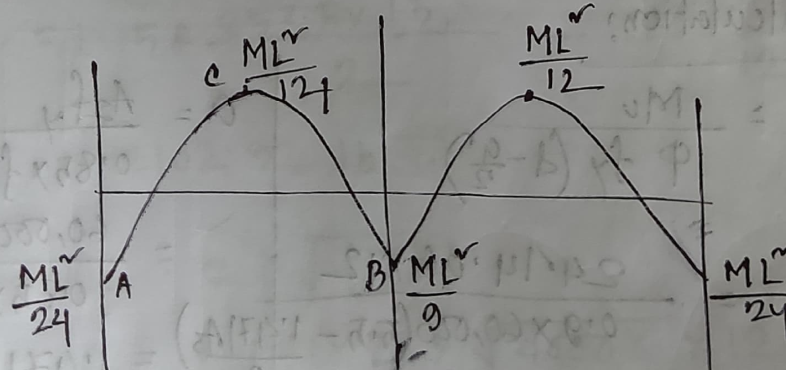
$$\text{Live load} = 100 \text{ psf}$$

$$L.L = 1.2 D.L + 1.6 L.L$$

$$= 1.2 * 81.25 + 1.6 * 100$$

$$\therefore W_u = 257.5 \text{ psf}$$

Moment calculation:




// At exterior support (A) $= -\frac{WL^2}{24} = -\frac{257.5\times 15^2}{24} = -2414.06$ lb-ft

// At ~~mid span~~ interior support (B) $= -\frac{WL^2}{9} = -\frac{257.5\times 15^2}{9} = -6437.5$ lb-ft

* At ~~interior~~ support (c) mid span $= -\frac{WL^2}{12} = -\frac{257.5 \times 15^2}{12}$

$= \cancel{4828.125}$

$= 4138.39$ lb.

4. Depth check:

$$M_u = \phi \rho b d^2 f_y \left(1 - 0.59 \frac{\rho f_y}{f_c'}\right)$$

$$\rho = 0.85 \beta_1 \frac{f_c'}{f_y} \times \frac{\varepsilon_u}{\varepsilon_u + \varepsilon_y}$$

$$= 0.85 \times 0.85 \times \frac{4000}{60,000} \times \frac{0.003}{0.003 + 0.005}$$

$$= 0.018$$

$$6437.5 \times 12 = 0.9 \times 0.018 \times 12 \times d^2 \times 60,000 \left(1 - 0.5 \frac{0.018 \times}{40}\right)$$

$d_{req} = 2.76$ inch

effective thickness, $t_{eff.} = (6.5 - 1) = 5.5$.

$d_{req} < t_{eff}$. Design OK

5. ~~S~~ Steel calculation:

$$A_s = \frac{M_u}{\phi f_y \left(d - \frac{a}{2}\right)}$$

$$a = \frac{A_s f_y}{0.85 \times f_c' \times b} = \frac{60,000 \times A_s}{0.85 \times 4000} = 1.471 A_s$$

$$A_s \text{ (at exterior)} = \frac{2414.06 \times 12}{0.9 \times 60,000 \left(5.5 - \frac{1.471 A_s}{2}\right)}$$

$A_s = 0.1$ in$^2$

providing #3 bar @ $= \frac{0.11 \times 12}{0.1} = 13.2''$ c/

$$A_s(\text{mid span}) = \frac{\overset{4138.39}{\cancel{6437.5}} \times 12}{0.9 \times 60000 \left(5.5 - \frac{1.471 A_s}{2}\right)}$$

$A_s = 0.17 \text{ in}^2$

providing #3 bar @ $= \frac{0.11 \times 12}{0.17} = 7.76''$ c/c

$$A_s(\text{interior span}) = \frac{6437.5 \times 12}{0.9 \times 60{,}000 \times \left(5.5 - \frac{1.471 A_s}{2}\right)}$$

$A_s = 0.26 \text{ in}^2$

providing #3 bar @ $= \frac{0.11 \times 12}{0.26} = 5.07''$ c/c

6. Distribution reinforcement:

$A_s(\text{min}) = 0.0018\, bt$

$= 0.0018 * 12 * 6.5$

$= 0.14$

providing #3 bar @ $= \frac{0.11 \times 12}{0.14} = 9.42''$ c/c

7. shear check:

$$V_u = 1.15 * \frac{WL}{2} - \frac{Wd}{12}$$

$$= 1.15 * \frac{257.5 \times 15}{2} - \frac{257.5 \times 5.5}{12}$$

$= 2102.92$ lb

$V_{allowable} = 2\phi\sqrt{f_c'}\, bd$

$= 2 \times 0.75 \times \sqrt{4000} \times 12 \times 5.5$

$= 6261.31$ lb

$\therefore V_u < V_{all}$ Design is ok

8) Bond check:

$$U_{dev} = \frac{V_{max}}{\varepsilon_0 (d - a/2)}$$

$$= \frac{1931.25}{2.79 \times (5.5 - \frac{0.38}{2})}$$

$$= 130.36 \text{ lb/in}$$

$$V_{max} = \frac{WL}{2} = \frac{257.5 \times 1}{2}$$

$$= 1931.25$$

$$\varepsilon_0 = n\pi D$$

$$= \frac{b}{spacing} \times \pi \times D$$

$$= \frac{12}{5.07} \times \pi \times 0.3$$

$$= 2.79$$

$$a = \frac{A_s f_y}{0.85 f_c' b} = \frac{0.26 \times 60{,}0}{0.85 \times 4}$$

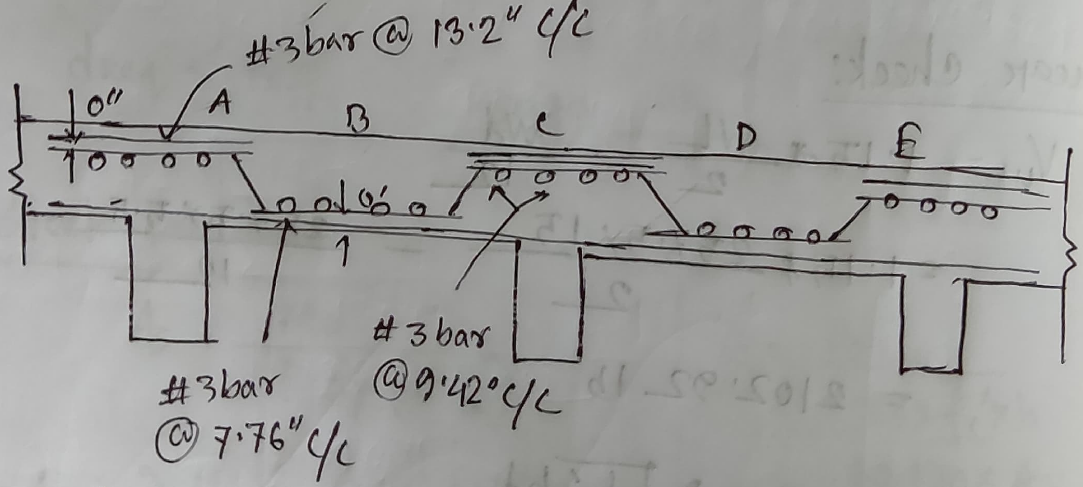
$$= 0.38$$

$$U_{all} = \frac{6.7\sqrt{f_c'}}{D}$$

$$= \frac{6.7 \times \sqrt{4000}}{0.374}$$

$$= 1129.99$$

$U_{dev} < U_{all}$ Hence, Design is ok. Ans.




- At support A and E,

- At support C,

WSD

Problem-02: A reinforced concrete slab is built integrally with its appearance support and consists of three equal spans, each span of 11 ft and the working live load is 110 psf. If $f_c' = 3000$ psi, $f_y = 50{,}000$ psi. Design the slab using WSD.

Solution:

Considering the slab is both end continuous

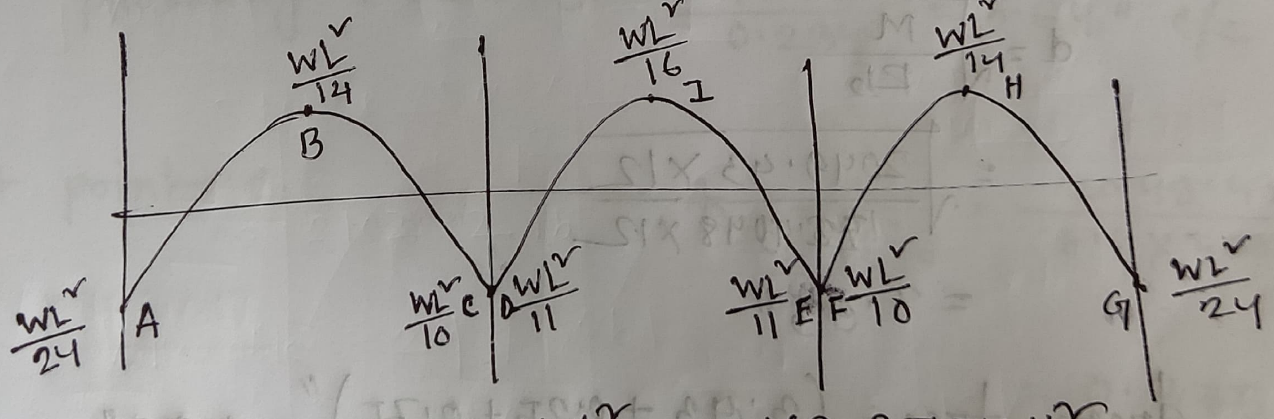
$$\therefore t = \frac{l}{28} = \frac{11 \times 12}{28} = 4.71 \text{ ft} \approx 4.75 \text{ ft}$$

Load calculation:

$$\text{Dead load} = \frac{t}{12} \times 150 \text{ psf}$$
$$= 59.375 \text{ psf}$$

$$T.L = 59.375 + 110$$
$$= 169.375 \text{ psf}$$

Moment calculation:




$$\text{Moment At point A, G} = -\frac{WL^2}{24} = \frac{169.375 \times 11^2}{24}$$
$$= 853.93 \text{ lb-ft}$$

$$\text{Moment at point B, H,} = +\frac{WL^2}{14} = \frac{169.375 \times 11^2}{14}$$
$$= 1463.88 \text{ lb-ft}$$

Moment at point I $= +\frac{wl^2}{16} = 1280.89$ lb-ft

Moment at point C, F $= -\frac{wl^2}{10} = 2049.43$ lb-ft

Moment at point D, E $= -\frac{wl^2}{11} = 1863.125$ lb-ft

<u>Depth check</u>

$$n = \frac{E_s}{E_c} = \frac{29\times10^6}{57000\sqrt{3000}} = 9$$

$$r = \frac{f_s}{f_c} = \frac{0.4 \times 50000}{0.45\times 3000} = 14.81$$

$$K = \frac{n}{n+r} = \frac{9}{9+14.81} = 0.378$$

$$j = 1-\frac{K}{3} = 1-\frac{0.378}{3} = 0.874$$

$$R = \frac{1}{2}f_c jk = \frac{1}{2}\times(0.4[illegible]\times3000)\times [illegible]$$
$$= 223[illegible]$$

$$d = \sqrt{\frac{M}{Rb}}$$
$$= \sqrt{\frac{2049.43\times12}{223[illegible]\times12}}$$
$$= 3.03''$$

~~dreq~~ treq $= (3.03 + 0.25 + 0.75)'' = 4.03''$

treq < tassume

Design OK

deffective $= (4.75 - 1) = 3.75''$

Steel calculation

At point A, G $\longrightarrow$ $A_s = \dfrac{M}{f_s jd} = \dfrac{853.93 \times 12}{(0.4 \times 50{,}000) \times 0.874 \times 3.75}$

$= 0.156 \text{ in}^2$

providing # 3 bar @ $= \dfrac{0.11 \times 12}{0.156} = 8.46'' \text{ c/c}$

At point B, H $\longrightarrow$ $A_s = \dfrac{M}{f_s jd} = \dfrac{1463.88 \times 12}{(0.4 \times 50{,}000) \times 0.875 \times 3.75}$

$= 0.268 \text{ in}^2$

providing # 3 bar @ $= \dfrac{0.11 \times 12}{0.268} = 4.92'' \text{ c/c}$

At point I $\longrightarrow$ $A_s = \dfrac{M}{f_s jd} = \dfrac{1289.89 \times 12}{0.4 \times 50{,}000 \times 0.875 \times 3.75}$

$= 0.234 \text{ in}^2$

providing # 3 bar @ $= \dfrac{0.11 \times 12}{0.234} = 5.64'' \text{ c/c}$

At point C, F $\longrightarrow$ $A_s = \dfrac{M}{f_s jd} = \dfrac{2049.43 \times 12}{0.4 \times 50000 \times 0.875 \times 3.75}$

$= 0.375 \text{ in}^2$

providing # 3 bar @ $= \dfrac{0.11 \times 12}{0.375} = 3.52'' \text{ c/c}$

At point D, E $\longrightarrow$ $A_s = \dfrac{M}{f_s jd} = \dfrac{1863.125 \times 12}{0.4 \times 50000 \times 0.875 \times 3.75}$

$= 0.34 \text{ in}^2$

providing # 3 bar @ $= \dfrac{0.11 \times 12}{0.34} = 3.88'' \text{ c/c}$

## Distribution reinforcement

$f_y = 50{,}000$ psi

so, $A_s = 0.0020bt$

$= 0.0020 \times 12 \times 4.75$

$= 0.114 \text{ in}^2$

## Shear check

$$V_w = 1.15 \frac{WL}{2} - \frac{Wd}{12}$$

$$= 1.15 \frac{169.375 \times 11}{2} - \frac{169.375 \times 3.75}{12}$$

$$= 1018.36 \text{ lb}$$

$$V_{all} = 1.1\sqrt{f_c'}\, bd = 1.1 \times \sqrt{3000} \times 12 \times 3.75$$

$$= 2711.22 \text{ lb}$$

$V_{act} < V_{all}$ [Design ok]

## Bond check

$$U_{dev} = \frac{V_{max}}{\Sigma_o jd}$$

$$= \frac{931.56}{7.3899 \times 0.874 \times 3.75}$$

$$= 38.46$$

$$U_{all} = \frac{3.4\sqrt{f_c'}}{D} = \frac{3.4\sqrt{3000}}{0.69}$$

$$= 269.89$$

$U_{all} > U_{dev}$ [design ok]

$$V_{max} = \frac{WL}{2}$$

$$= \frac{169.375 \times 11}{2}$$

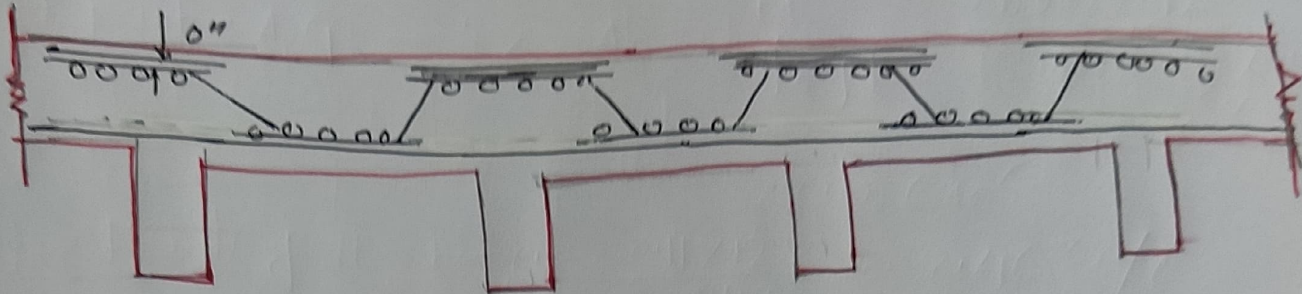
$$= 931.56$$

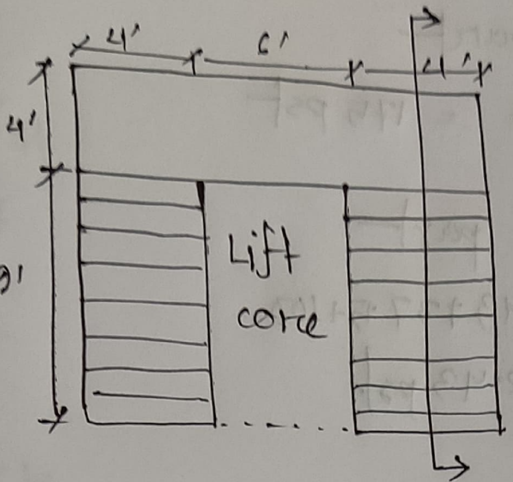
$$\Sigma_o = n\pi D$$

$$= \frac{12}{3.52} \times \pi \times 0.$$

$$= 7.3899$$

Working diagram

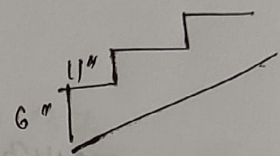





$LL = 100$ psf

$f_c' = 3000$ psi

$f_y = 50,000$ psi




Design the staircase by using WSD method

1. Thickness:

Assume thickness of slab = 6"

2. Load calculation:

$$\text{Dead load} := \frac{t}{12} \times 150$$

$$= \frac{6}{12} \times 150$$

$$= 75 \text{ psf}$$

~~Live load~~

$$\text{for top} = \frac{R}{2} = \frac{6/2}{12} = 0.75 \text{ psf}$$

$$\text{for inclined portion} = 75 \times \frac{\sqrt{6^2 + 11^2}}{11}$$

$$= 85.43$$

$$\text{load for step} = \frac{6}{2 \times 12} \times 150 = 37.5$$

~~T.L = D.L + L.L~~

=

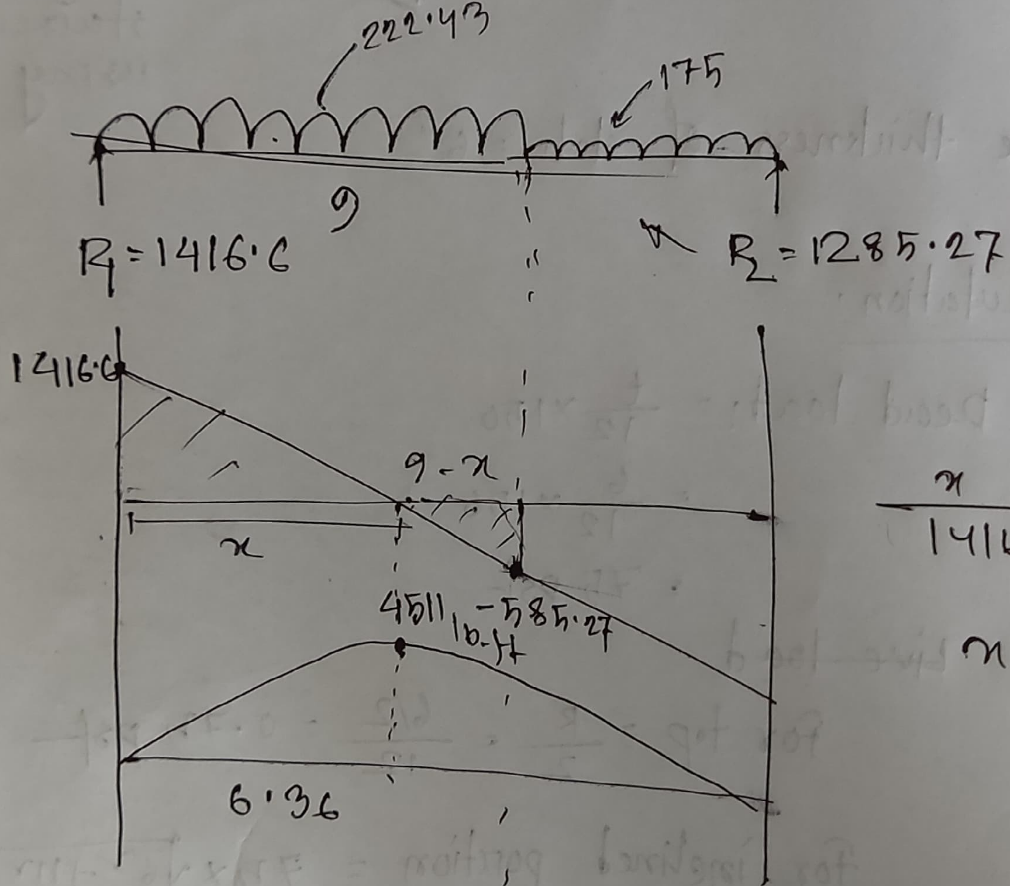
Total load of straight part

$= 75 + 100 = 175$ psf

Total load of inclined part

$= 85.43 + 37.5 + 100$

$= 222.43$ psf




$$\frac{x}{1416.6} = \frac{9-x}{585.27}$$

$x = 6.37'$

~~$n = 9$~~ $\quad n = \frac{E_s}{E_c} = 9$

$$r = \frac{f_s}{f_c} = \frac{0.5 \times 50{,}000}{0.45 \times 3000}$$

$= 14.81$

$$k = \frac{n}{n+r}$$

$$= \frac{9}{9+14.81}$$

$$= 0.37$$

$$j = 0.87$$

$$R = \frac{1}{2} f_c j k$$

$$= \frac{1}{2} \times (0.45 \times 3000) \times 0.87 \times 0.37$$

$$= 223$$

$$d = \sqrt{\frac{M}{Rb}}$$

$$= \sqrt{\frac{4511 \times 12}{223 \times 12}}$$

$$= 4.54$$

$t = 4.5 + 1 = 5.5''$ ok

$$A_s = \frac{M}{f_s j d}$$

$$= \frac{4511 \times 12}{20{,}000 \times 0.875 \times 5.6}$$

$$= 0.69$$

<u>Distribution:</u>

$$A_s = 0.0020bt$$

$$= 0.002 \times 12 \times 6$$

$$= 0.144 \text{ in}^2$$