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Section: A
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Question No:- 1

Given Data:-

Width, $b = 10''$ depth, $h = 20''$
Live load $= 2.47$ kip/ft.
dead load $= 1.05$ kip/ft.
Span, $l = 18$ ft.
f_y (Tensile strength of steel) $= 60$ ksi
f_c' (compressive strength) $= 4$ ksi
$d' = 2.5''$ assume.

Step No:- 1

Effective Depth of beam

$$d = 20 - 3$$
$$d = 17''.$$

Step No:- 2

We will now first check the capacity of beam as a singly reinforced beam.

$$\rho_{max} = 0.85 \times \beta \times \frac{f_c'}{f_y} \times \left(\frac{\varepsilon_u}{\varepsilon_u + \varepsilon_y}\right)$$

$\because$ $\varepsilon_u = 0.003 \rightarrow$ constant for concrete.
$\varepsilon_y = 0.005 \rightarrow$ constant for concrete.

Since $f_c' = 4$ ksi $\rightarrow \beta = 0.85$.

$$\Rightarrow \rho_{max} = 0.85 \times 0.85 \times \frac{4}{60}\left(\frac{0.003}{0.003 + 0.005}\right)$$

$$\boxed{\rho_{max} = 0.0180}$$

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Step No:- 3 :-

As we Know that;

$$\rho_{max} = \frac{A_{st}}{b \times d}$$

$$\rho_{max} \times b \times d = A_{st}$$

$$A_{st} = 0.018 \times 10'' \times 17''$$

$$\boxed{A_{st} = 3.06 in^2}$$

Step No:- 4 Finding moment.

$$M_{u_2} = \phi \times A_{st} \times f_y \times \left(d - \frac{a}{2}\right)$$

for "a" we use formula.

$$a = \frac{A_{st} \times f_y}{0.85 \times f_c' \times b} \qquad a = \frac{3.06 \times 60}{0.85 \times 4 \times 10}$$

$$\boxed{a = 5.4''}$$

$$M_{u_2} = 0.90 \times 3.06 \times 60 \times \left(17 - \frac{5.4}{2}\right)$$

$$\boxed{M_{u_2} = 2362.93 \text{ Kip-inch}}$$

Step 5 :-

Now since safty factored moment is not given we will calculate it.

⇒ Beam self weight :

$$= b \times t \times \gamma_c$$

∴ Since for R.C.C, $\gamma = 150 lb \times ft^3$

$$= \frac{10}{12''} \times \frac{20}{12''} \times 150 lb/ft^3$$

$$= 208.33 \; lb/ft$$

or

$$= \boxed{0.20833 \text{ Kip/ft.}}$$

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Step No:- 6 Total factored load :-

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

$= 1.2(1.05 + 0.20833) + 1.6(2.4)$

$\boxed{W_T = 5.349 \text{ kip/ft.}}$

Step No:- 7 Ultimate factored Moment.

$M_u = \frac{(5.349)(18)^2}{8} \times 12''$

$\boxed{M_u = 2599.614 \text{ kip-inch.}}$

Now since $M_u > M_{u_2}$ this confirms that the given beam is a doubly reinforced beam.

$2599.614 > 2362.9 \text{ kip-inch.}$

Step No:- 8 Difference b/w external applied moment and the moment actually being raised by the bar.

$M_{u_1} = M_u - M_{u_2}$

$M_{u_1} = 2599 - 2362.9$

$\boxed{M_{u_1} = 236.1 \text{ kip-inch.}}$

This is the extra moment for which we will find the steel area and then provide it in compression zone.

Step No:- 9 Steel Area for Compression Zone.

$M_{u_1} = \phi \times A_{st}' \times f_y \times (d - d')$

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$$A_{st}' = \frac{M_{u1}}{\phi \times f_y \times (d-d')}$$

$$A_{st}' = \frac{236.1}{0.90 \times 60(17-2.5')}$$

$$\boxed{A_{st}' = 0.301 \text{in}^2}$$

Step 10 :- Total Steel Area (Provided in tension zone).

$$A_s = A_{st} + A_s'$$

$$A_s = \cancel{\phi}\,3.06 + 0.301$$

$$\boxed{A_s = 3.361 \text{in}^2}$$

Step 11 :- Finding Bar No. & Size.

A. Tension Zone :-

Bar #8 is selected.

$$\text{dia} = 8/8 = 1''$$

$$\text{Area} = \frac{\pi}{4}(1)^2$$

$$\boxed{A_b = 0.785 \text{in}^2}$$

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

$$= \frac{3.361}{0.785}$$

No. of bars = 4.28 ≅ 5 bars.

B. Compression Zone :-

Bar # 6 is selected.

$$d = 6/8 = 0.75''$$

$$\text{Area} = \frac{\pi}{4}(0.75)^{4} \qquad \boxed{A_b = 0.44 \text{in}^2}$$

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No. of bars $= \frac{A_{st}}{A_b} = \frac{0.301}{0.44} = 0.68 \approx 1$ bar.

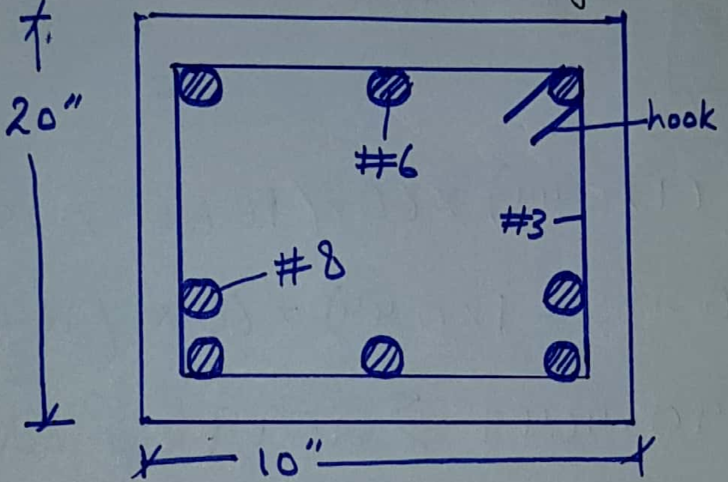
Step 12:- Checking the minimum width of beam to see if the bars fit in 1 layer or not.

$b_{min} =$ 2 x clear cover + 2 x dia of stirrups + No. of bar x dia of one bar + No. of spaces x dia of bars

$= 2(1.5) + 2\left(\frac{3}{8}\right) + 5\left(\frac{8}{8}\right) + 4\left(\frac{8}{8}\right)$

$= \boxed{12.75 > 10''}$

Since b_{min} is greater than the given width so provided in multipule layers.



Also finding effective depth & cover.

=> Effective depth $(d) = 20 - 1.5 - \left(\frac{8}{8}\right) - \left(\frac{3}{8}\right) - \frac{1}{2}\left(\frac{8}{8}\right)$

$\boxed{d = 16.62''}$

=> Effective cover $(d') = 1.5 + \frac{3}{8} + \frac{1}{2}\left(\frac{6}{8}\right)$

$\boxed{d' = 2.25''}$

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Step No:- 9 Design Moment

This step is done to find whether these bars have the capacity to bear the external ultimate factored load or not.

$$Md = \phi \times [Ast' \times fy \times (d-d') + (Ast - Ast') \times fy (d - a/2)].$$

$$\Rightarrow a = \frac{(Ast - Ast') \times fy}{0.85 \times fc' \times b}.$$

$$= \frac{(5 \times 0.785) - (1 \times 0.44) \times 60}{0.85 \times 4 \times 10}$$

$$\boxed{a = 6.15''}$$

$$Md = 0.90 [(1 \times 0.44) \times 60 \times (16.62 - 2.25) + (5 \times 0.785 - 1 \times 0.44) \times 60 \times (16.62 - \frac{6.15}{2})$$

$$Md = 2890.4647 > 2599 \text{ kip-inch}.$$

Since

md > Mu,

Design is OK!

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Question No:-2

a- Bond Stress:-

Bond stress is the result of bonding between the reinforcement steel and concrete surface. It varies depending upon the type of steel and type of concrete used. Bond stress resists any force that tries to pull the rods out from the concrete.

Development Length:-

It is the minimum Length of bar that is embedded in concrete beyond any section to develop its full strength. Development length is provided in column beam joint or column footing joint.

b- Doubly reinforced beams Requirements:-

They are provided because;

1. To increase the moment carrying capacity of the section
2. Minimum compressions reinforcement is provided to hold the shear reinforcement in position and for increasing the ductility of beam.
3. To ensure safety against reversal of stresses in the structure due to wind forces, seismic forces and temperature stresses.
4. When load demand on beam is high and also beam depth is ressricted due to reasons.
5. When a beam has to be designed for restricted dimensions, we design a doubly reinforce beam

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c. T-beam Analysis :-

A T-beam has a beam & slab composite section. A T-beam is more economical than rectangular beam. Due to monolithic casting of beam and slab, the slab depth becomes lesser than traditional beam & results in economical structor.

When $a > hf$

T-beam analysis.

a = depth of compression block.
hf = height of flange.

Rectangular Beam :-

In the stress-block diagram of rectangular beam, the top fibers are subjected to maximum compression that linearly reduces till the neutral axis.

When $a \leq hf$

Rectangular beam analysis.

d. Effect of Strength Reduction Factor on flexural Strength :-

ϕ = strength reduction factor
=> It is the ratio of elastic strength & yield strength.

For Flexure (Bending moment) $\phi = 0.90$

=> this means that 90% strength is being considered for the moment and the remaining 10% strength will be used for future accidental moments.

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e- Designing Methods :-

1- Allowable Stress Design Method
2- Ultimate Strength Design Method.

=> In the ASD method all loads are considered as service loads and no factor is applied for the purpose of increasing the service loads.
=> This method uses strength or ultimate level design approach.
=> The principle of this method is that the stresses developed in the structural members should not exceed a certain limit of elastic limit

=> The USD method is primarily based on strength concept of concrete.
=> Low cost design method.
=> Its considered to design critical combination of loads.

Best Method:-

USD is the best method because it is much more economical and it also gives us much slender sections for columns and beams compared to other design methods.

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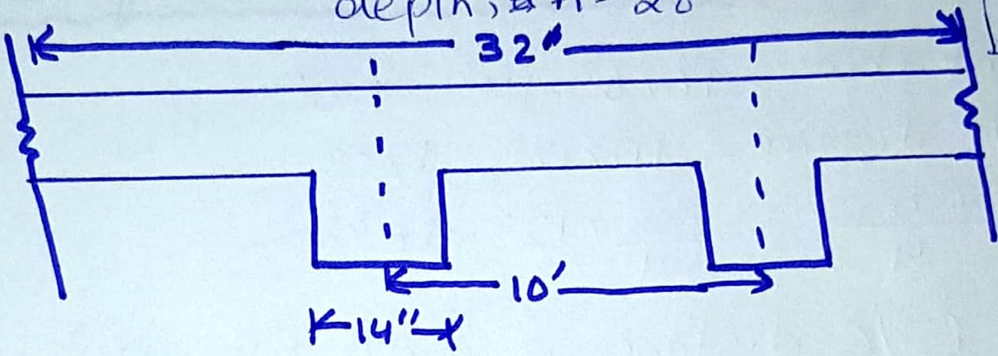
Question No:- 3

Given Data:-

C/Centre distance = 10'
D.L = 50 lb/ft²
S.S = 225 lb/ft²
fy (tensile strength of steel) = 60 ksi
fc' (compressive strength) = 4 ksi
width of web, bw = 14"
slab thickness, ~~hf~~ = 6"
depth, ~~d~~ h = 28".

$d = 28 - 3$
$\boxed{d = 25}$



Step No:- 1 Finding Ultimate Factored Moment

$$Mu = \frac{Wu \times l^2}{8}.$$

=> Since "Wu" is not given so we will find it

=> Beam self weight

$$Wt = b \times t \times \gamma c$$

$\gamma c = 150 \rightarrow$ constant for R.C.C.

$$Wt = \frac{14}{12"} \times \frac{28}{12"} \times 150$$

$$Wt = 408.33 \text{ lb/ft}.$$

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=> Total Factored load

$= 1.2(50 + 408.33) + 1.6(225)$.

$= 909.99$ lb/ft.

$= 0.909$ kip/ft.

=> Finding Moment.

$$\frac{wl^2}{8} = \frac{0.909 \times (32)^2}{8} \times 12$$

$$= \boxed{1396.22 \text{ kip-inch}}$$

Step No:- 2 Effective Breadth of Beam.

1. $16h_f + b_w = 16 \times 6'' + 14'' = 110''$
2. C/C distance $= 10 \times 12'' = 120''$
3. $\frac{\text{span}}{4} = \frac{32}{4} \times 12'' = 96''$.

Since C/C distance is given we will use only 1st, 3rd & 4th condition & ignore the 2nd condition

=> Now since least value is 96'' so we will select $\boxed{b_e = 96''}$

Step No:- 3 Now Checking Weather its Rectangular or T-beam

Let us assume that height of flange is equal to the depth of compression block.

$a = h_f = 6''$

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Trial 1#

$$A_{st} = \frac{M_u}{\phi \times f_y \times (d - a/2)}$$

$$\boxed{\phi = 0.90}$$

$$A_{st} = \frac{1396.23}{0.90 \times 60(25 - 6/2)}$$

$$\boxed{A_{st} = 1.1752 \text{ in}^2}$$

Trial 2#

Now finding "a" fom formula.

$$a = \frac{A_{st} \times f_y}{0.85 \times f_c' \times b} = \frac{1.175 \times 60}{0.85 \times 4 \times 96}$$

$$a = 0.216''$$

Since $a < h_f$

So it is a rectangular beam design.

$$A_{st} = \frac{1396.23}{0.90 \times 60 \times (25 - \frac{0.2}{2})}$$

$$\boxed{A_{st} = 1.03 \text{ in}^2}$$

Trial 3#

$$a = \frac{1.03 \times 60}{0.85 \times 4 \times 96}$$

$$a = 0.18''$$

$$A_{st} = \frac{1396.23}{0.90 \times 60(25 - \frac{0.18}{2})} = \boxed{1.03 \text{ in}^2}$$

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Step No:- 4 Checking ρ_{max} & ρ_{min}

ρ = reinforcement ratio (This tells us that how much steel has been provided in the cross-sectional area of steel.

ρ_{max} = The max area of steel that we can provide in cross-section.

$$\rho_{max} = 0.85 \times B \times \frac{f_c'}{f_y}\left(\frac{\varepsilon_u}{\varepsilon_u + \varepsilon_t}\right)$$

∴ ε_u = ultimate strain in concrete

∴ ε_t = tensile strain in concrete.

$$\rho_{max} = 0.85 \times 0.85 \times \frac{4}{60}\left(\frac{0.003}{0.003+0.005}\right)$$

$$\boxed{\rho_{max} = 0.018}$$

ρ_{min} = The minimum area of steel that we can provide in cross-section.

$$\rho_{min} = \frac{200}{f_y} = \frac{200}{60{,}000} = \boxed{0.0033}$$

ρ = The steel which we are originally providing in the beam.

$$\rho = \frac{A_{st}}{b \times d} = \frac{1.03}{14 \times 25}$$

$$\boxed{\rho = 0.0029.}$$

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Now since $\rho < \rho_{min}$

So;

$$\rho_{min} = \frac{A_{st}}{b \times d} \Rightarrow A_{st} = \rho_{min} \times b \times d$$

$$A_{st} = 0.003 \times 14 \times 25$$

$$\boxed{A_{st} = 1.05\,in^2}$$

Step 5 #:- Selection of Bar No. & Size.

Using 8 # bar.

$d = 8/8 = 1"$

Area = $0.785\,in^2$

$$\text{No. of bars} = \frac{1.05}{0.785} = 1.3 \approx 2 \text{ bars}.$$

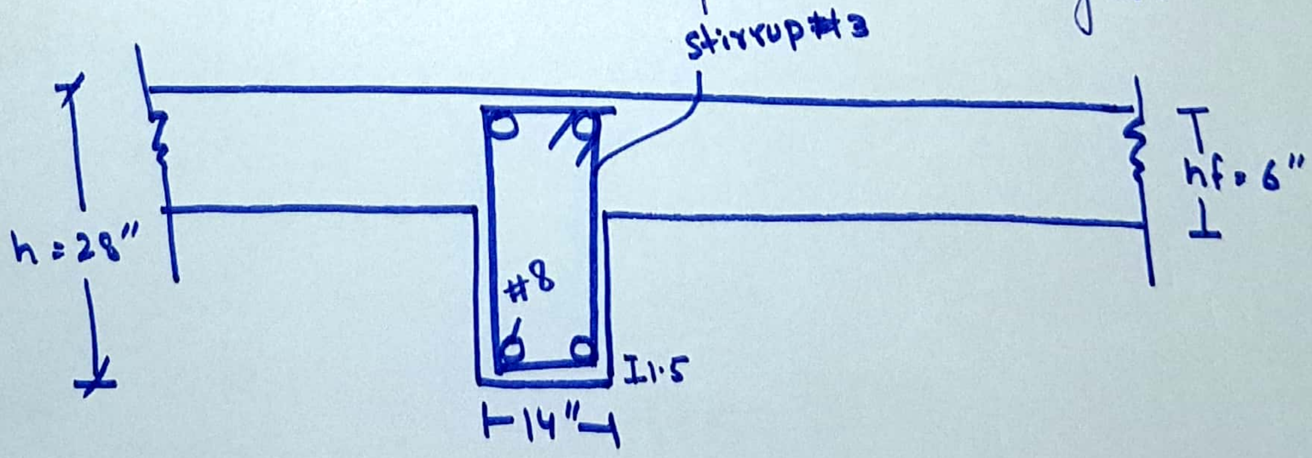
Step 6 #:- Minimum Width

$$b_{min} = 2(1.5) + 2(3/8) + 2(8/8) + 1(8/8)$$

$$b_{min} = 6.75"$$

$b_{min} < 14"$

So we can provide in 1 layer.



Step # 7 :- Design Moment

$$Md = \phi \times fy \times \underset{\downarrow}{Ast} \times (d - a/2)$$

(Ab × No. of bars)

$Ast = 0.785 \times 2$

$Ast = 1.57 in^2$

$$a = \frac{1.57 \times 60}{0.85 \times 4 \times 96} = 0.2''$$

$Md = 0.90 \times 60 \times 1.57 \times (25 - 0.2/2)$

$= 2111.02$ kip-inch.

$2111.02 > 1396.23$

So, desig is okay.

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