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Question# 01:

A rectangular beam that must carry a service load (live) of 2.47 kips/ft and a calculated dead load of 1.05 kips/ft. (without self weight) on an 18 ft Simple Span is limited to 10 inches width and 20 inches total depth for architectural reasons.
If $f_y = 60{,}000$ psi and $f'_c = 4000$ psi. What steel area must be provided? Draw sketch of your final design.

Given data:

Live load = 2.47 kips/ft or 2470 lb/ft

Dead load = 1.05 kips/ft or 1050 lb/ft

Span = L = 18 ft

width = b = 10"

Depth = h = 20"

f_y = 60,000 psi or 60 ksi

f'_c = 4000 psi or 4 ksi

Solution:-

As we know that

Effective depth $= d = h - 3$

$= 20'' - 3''$

$\Rightarrow d = 17''$

Assume that

Effective cover $= d' = 3''$

Step # 01 :-

To check the capacity of the Section as singly reinforced beam,

For that, we know

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

As we have given that

$f'_c = 4\,ksi$

So $\beta = 0.85$

So,

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

$$\Rightarrow \boxed{\rho_{max} = 0.0181}$$

Step#02:

To find area of Steel, Ast we know that

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

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

$$= 0.0181 \times 10 \times 17$$

$$\boxed{A_{st} = 3.077 \text{ in}^2}$$

Step#03:

To find moment for the above Ast, we know that

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

first we have to find depth of compression block, a by

$$a = \frac{A_{st} \times f_y}{0.85 \times f'_c \times b}$$

$$= \frac{3.077 \times 60}{0.85 \times 4 \times 10}$$

$$\Rightarrow a = 5.43''$$

So,

$$M_{U_2} = 0.90 \times 3.077 \times 60 \times \left(17 - \frac{5.43}{2}\right)$$

$$\Rightarrow \boxed{M_{U_2} = 2373.567 \text{ kip-inch}}$$

Step # 04 :-

Total factored load

Beam self weight/ft = $b \times h \times \gamma_c$

$$= \left(\frac{10}{12}\right)' \times \left(\frac{20}{12}\right)' \times (150) \quad \because \gamma_c \text{ for RCC} = 150 \text{ lb/ft}^3$$

$$= 208.33 \text{ lb/ft}$$

we know that

Total factored load = 1.2 D.L + 1.6 L.L

$$= 1.2(1050 + 208.33) + 1.6(2470)$$

$$= 5461.996 \text{ lb/ft}$$

$$= 5.462 \text{ kips/ft}$$

Step # 05:-

Ultimate factored moment

Here,

$$UFM = \frac{w \times l^2}{8}$$

$$= \frac{5.462 \times (18)^2}{8}$$

$$= 221.211 \times 12$$

$$\boxed{M_U = 2654.532 \text{ kip-inch}}$$

As

$$M_u > M_{u2}$$

$\Rightarrow 2654.532 > 2373.567$

it means, the section do not have the capacity to resist the moment produced as a singly reinforced beam.

↳ So we have to design it as doubly reinforced beam.

Step #06:

To find the extra moment,

$$M_{u1} = M_u - M_{u2}$$

$$= 2654.532 - 2373.567$$

$$\boxed{M_{u1} = 280.965 \text{ Kips-inch}}$$

Step #07:-

To find Ast in compression zone

As we have

$$M_{u1} = \phi \times A'_s * f_y \times (d - d')$$

$$\Rightarrow A'_s = \frac{M_{u1}}{\phi \times f_y \times (d - d')}$$

$$= \frac{280.965}{0.90 \times 60 \times (17 - 3)}$$

$$\boxed{A'_s = 0.372 \text{ in}^2}$$

Step#08:-

To find total steel area,

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

$$= 3.077 + 0.372$$

$$\boxed{A_s = 3.449 \text{ in}^2}$$

Step#09:-

Selection of Bars

Let try #10 bar.

So

$$\text{Number of bars} = \frac{A_s}{A_b}$$

$$= \frac{3.449}{1.227} \qquad \because A_b = \frac{\pi}{4} \times \left(\frac{10}{8}\right)^2 = 1.227 \text{ in}^2$$

$$= 2.81 \approx 3$$

So, we will use 3#10 bars in tension zone.

Now for compression zone,

Let try #4 bar,

then

$$\text{Number of bars} = \frac{A'_s}{A_b}$$

$$= \frac{0.372}{0.196} \qquad \because A_b = \frac{\pi}{4} \times \left(\frac{4}{8}\right)^2 = 0.196$$

$$= 1.898 \approx 2$$

So we will use 2#4 bar in compression zone

Step #10 :

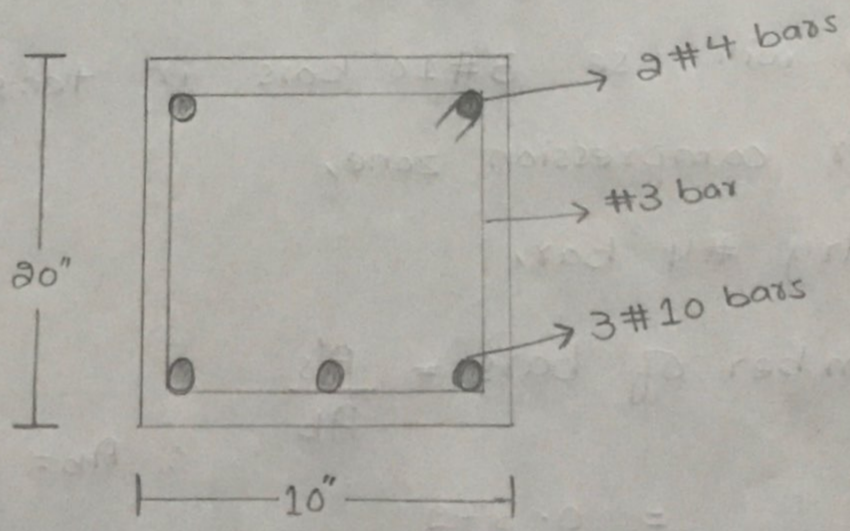
To check that the bars will be fit in one layer or not.

$$b_{min} = (2 \times c.c) + (2 \times \text{stirrup dia}) + \left[3 \times \left(\frac{10}{8}\right)''\right] + (2 \times \text{spacing})$$

$$= (2 \times 1.5) + \left[2 \times (3/8)''\right] + \left[3 \times \left(\frac{10}{8}\right)''\right] + \left[2 \times \left(\frac{10}{8}\right)''\right]$$

$$b_{min} = 10'' = b = 10''$$

So the bars can be provided in one layer.



Effective depth = d = $20 - 1.5 - \frac{3}{8} - \frac{1}{2}\left(\frac{10}{8}\right)$

$\Rightarrow d = 17.5''$

Effective cover = d' = $1.5 + \frac{3}{8} + \frac{1}{2}\left(\frac{4}{8}\right)$

$\Rightarrow d' = 2.125''$

Step # 11:

Design moment

$$M_d = \phi \times \left[A'_s \times f_y \times (d - d') + (A_s - A'_s) \times f_y \times \left(d - \frac{a}{2}\right)\right]$$

for this,

$$a = \frac{(A_s - A'_s) \times f_y}{0.85 \times f'_c \times b}$$

$\because A_s = 3 \times 1.227 = 3.681$

$\because A'_s = 2 \times 0.196 = 0.392$

$$= \frac{(3.681 - 0.392)\,60}{0.85 \times 4 \times 10}$$

$a = 5.804''$

$$\Rightarrow M_d = 0.90 \times \left[0.392 \times 60 \times (17.5 - 2.125) + (3.681 - 0.392) \times 60 \times \left(17.5 - \frac{5.804}{2}\right)\right]$$

$M_d = 2918.15$ Kip-inch $> M_u = 2654.532$

So design is OK!

Question # 03:-

A Concrete floor consist of parallel T beams Spaced 10 ft on centers and spanning 32 ft between supports. The 6 inch thick slab is cast monolithically with T beams webs having bw = 14" and total depth measured from the top of the slab of h = 28". The effective depth will be taken 3" less than the total depth. In addition to its own weight, each beam must carry a Superimposed D.L of 50 psf and service live load of 225 psf. Material strengths are fy = 60,000 psi and f'c = 4000 psi. Determine the required tensile steel area and select the reinforcement needed for a typical member. Draw sketch of your final design.

Given data:

c/c distance = 10'

Total Span = 32' = L

Slab thickness = 6" = height of flinge = h_f

web width = bw = 14"

depth = h = 28"

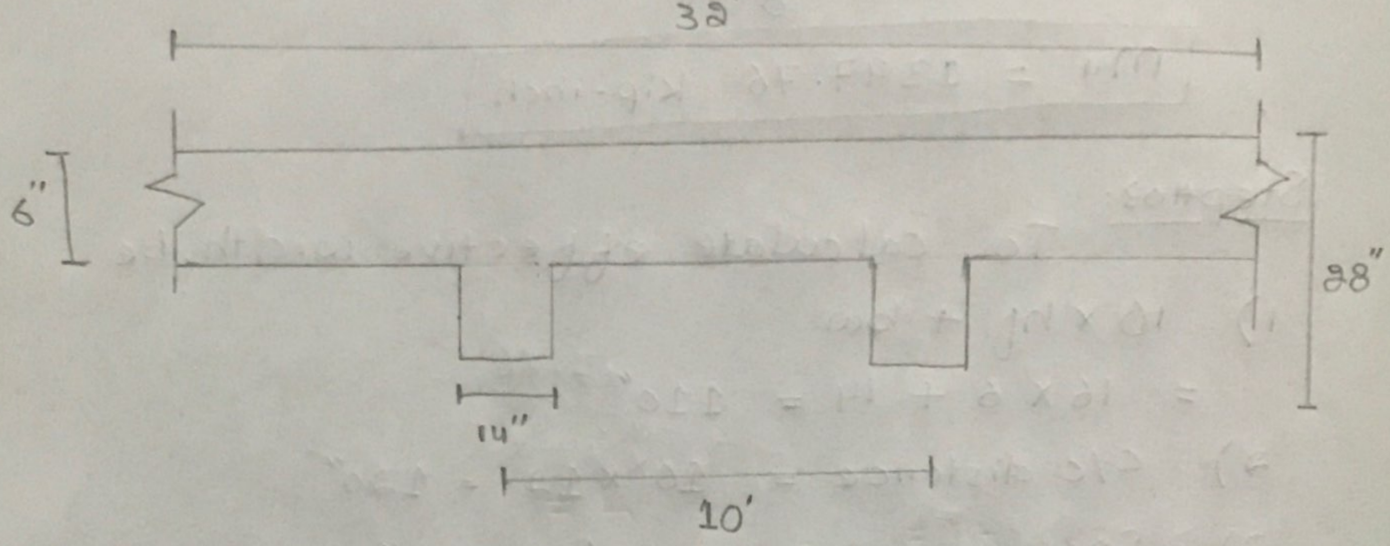
Dead load = 50 psf = 50 lb/ft^2 =

Live load = 225 psf = 225 lb/ft^2

$f'_c = 4000\,psi = 4\,ksi$

$f_y = 60{,}000\,psi = 60\,ksi$

Solution: effective depth $= h - 3 = 28 - 3 = 25''$



Step#01:- Total factored load

First of all, we have to find beam self weight per feet

$\Rightarrow W_t = b \times h \times \gamma_c$

$= \left(\frac{14}{12}\right)' \times \left(\frac{28}{12}\right)' \times 150\ lb/ft^3$

$\Rightarrow W_t = 408.33\ lb/ft$

As we know that, Total factored load

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

$= 1.2 \times (50 + 408.33) + 1.6 \times (225)$

$W_u = 909.996\ lb/ft$ or $0.91\ kip/ft$

Step#02:

Ultimate factored moment

$$M_u = \frac{w_u \times l^2}{8}$$

$$= \frac{0.91 \times (32)^2}{8} \times 12$$

$$\boxed{M_u = 1397.76 \text{ kip-inch}}$$

Step#03:

To calculate effective width, be

1) $16 \times h_f + b_w$

$= 16 \times 6 + 14 = 110''$

2) c/c distance $= 10 \times 12 = 120''$

3) $\frac{Span}{4} = \frac{32}{4} = 8' = 96''$

So, the $\boxed{b_e = 96''}$

Step#04:

To check which type of analysis is required

Trial#01:

Let suppose $a = h_f = 6''$

we know that

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

$$\Rightarrow A_{st} = \frac{1397.76}{0.90 \times 60 \times \left(25 - \frac{6}{2}\right)}$$

$$A_{st} = 1.177 \text{ in}^2$$

Trial # 02:

$$a = \frac{A_{st} \times f_y}{0.85 \times f'_c \times b_e}$$

$$= \frac{1.177 \times 60}{0.85 \times 4 \times 96}$$

$a = 0.216'' < h_f = 6''$, so ~~Analysis~~ Design by Rectangular beam

$$\Rightarrow A_{st} = \frac{1397.76}{0.90 \times 60 \times \left(25 - \frac{0.216}{2}\right)}$$

$$A_{st} = 1.04 \text{ in}^2$$

Trial # 03:-

$$a = \frac{1.04 \times 60}{0.85 \times 4 \times 96} = 0.191 \text{ in}$$

$$\Rightarrow A_{st} = \frac{1397.76}{0.9 \times 60 \times \left(25 - \frac{0.191}{2}\right)}$$

$$\boxed{A_{st} = 1.04 \text{ in}^2}$$

Step#05 :-

To check ρ_{max} and ρ_{min}

$$\rho_{max} = 0.85 \times \beta \times \frac{f'_c}{f_y} \times \left(\frac{\varepsilon_u}{\varepsilon_u + \varepsilon_t}\right)$$

$\because \beta = 0.85$ because $f'_c = 4$ ksi

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

$$\boxed{\rho_{max} = 0.0181}$$

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

As we know that

$$\rho = \frac{A_{st}}{b_e \times d}$$

$$= \frac{1.04}{14 \times 25}$$

$$\boxed{\rho = 0.00297}$$

So

$\rho_{min} < \rho < \rho_{max} \rightarrow$ not ok

because

$\rho_{min} < \rho$ not Satisfied here.

Now,

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

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

$$= 0.0033 \times 14 \times 25$$

$$\boxed{A_{st} = 1.155 \text{ in}^2}$$

Step#06:

Bar selection and no of bars

Let us try #8 bar, then

$$\text{No of bars} = \frac{A_{st}}{A_b} \qquad \because A_b = \frac{\pi}{4} \times \left(\frac{8}{8}\right)^2 = 0.785$$

$$= \frac{1.155}{0.785}$$

$$= 1.47 \approx 2$$

So we will take 2#8 bars as Main bars

Step#07:

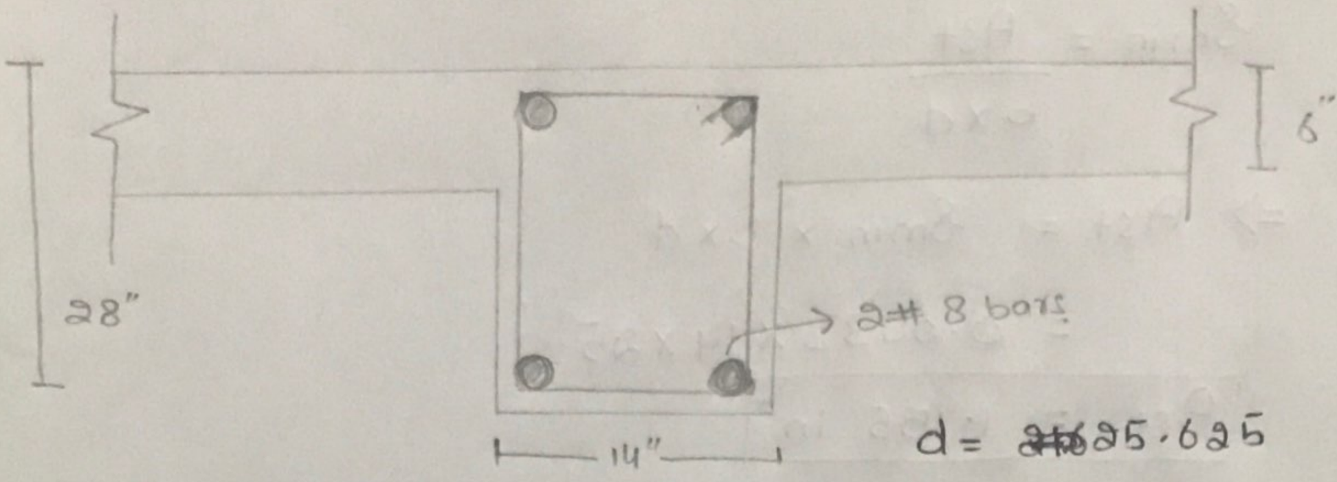
To check on minimum width,

b_{min} = 2 x C.C + 2 x Stirrup + 2 x Main bar + 1 x spacing

$$= (2 \times 1.5) + (2 \times 3/8) + (2 \times 8/8) + (1 \times 8/8)$$

$$= 6.75'' < 14''$$

So main bars are good in one layer.



d = 25.625

Step # 08: Design moment

As we know that

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

$$= 0.90 \times 60 \times 1.57 \times \left(25.625 - \frac{0.289}{2}\right)$$

$$\boxed{M_d = 2160.237}$$

$M_d > M_u$

Hence the design is ok.

#8 bar dia

$$A_{st} = 0.785 \times 2$$

$$= 1.57 \text{ in}^2$$

$$a = \frac{A_{st} \times f_y}{0.85 \times f'_c \times b_e}$$

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

$$= 0.289 \text{ in}$$

Question#02:

a) Briefly describe Bond Stress and Development length.

Bond Stress:

The stress acting on at the interface of the rebar and concrete that acts parallel to the bar as a result adhesion, mechanical interlock and frictional forces between the concrete and the steel is called Bond Stress.

↳ It helps in transfer of axial loads from steel to concrete by development of forces along the contact surface.

↳ we can not pull out the reinforced bar from the concrete when its hardened because the bond stress resist the bar from coming out.

↳ The bond between the reinforcement bar and the concrete is because of this bond stress

Development Length:

Development length is the the necessary length between the point of maximum stress in a bar and the end of a bar is called development length of reinforcement bars.

↳ we provide the development length, to develop a safe bond between the bar surface and the concrete so that no failure due to slippage of bar occurs during the ultimate loading condition.

b) In which conditions doubly reinforced beam can be used?

Answer: Doubly reinforced beam can be used when there is some restrictions (Architectural) on the dimensions and we can not increase the depth of the beam.

↳ Also we design doubly reinforced beam for safety factors.

↳ we can also provide doubly reinforced beam to increase the moment carrying capacity of the section.

c) Differentiate between T-beam analysis and rectangular beam analysis.

Answer: In case of T-beam designing, there is 2 analysis.

1) T- beam analysis
2) Rectangular beam analysis.

1) T-beam analysis:-

when $a > h_f$.

↳ when depth of the compression block (a) is greater than the height of flange or Slab thickness (h_f), then we design the T-beam on T-beam analysis method.

2) Rectangular beam analysis:-

$a \leq h_f$

↳ when depth of the compression block (a) is smaller or equal to the height of flange of the T-beam, then we design the beam as Rectangular beam.

d) Write short note on the effect of strength reduction factor on flexural strength.

Answer:-

The strength reduction factor ø decreases from tension controlled sections or Tension zone to compression controlled section or compression zone to increase safety, in the design of flexural strength

Strength reduction factor ø is the ratio of elastic strength and yield strength.

Strength reduction factor for flexural strength (load, moment) is ø = 0.90 or 90% which means that 90% of the strength value is considered here in designing and the rest of the percentage is for the future accidental purpose or safety purpose.

e) Briefly describe design methods, which one of them can be used for design of different structural members and why?

Methods of Designing:-

There are two methods for structural designing.

1) USD (Ultimate strength design)
2) ASD (Allowable strength design).

1) USD:

It is also called load factor method. because we use factored load while designing on this method.

↳ USD is the best method for designing different structural.

↳ It provides more safety.

↳ Tensile strength of concrete is neglected in USD

↳ Factored load in ultimate strength design can be calculated as

$$F.L = 1.2 \times D.L + 1.6 \times L.L$$

2) ASD:

Allowable strength design method is also called Working Stress Design method.

- It is based on the principal that Stresses developed in the structural members should not exceed a certain fraction of elastic limit.
- This is an old method of design.
- In this method, all loads are taken as service loads and no factor is applied to increase those service loads
- The loads can be calculated by ASD as

$$W = D \cdot L + L \cdot L$$

The End

Thank You