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Subject : PRCD-I

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Section : B

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QNo 1

A rectangular beam that must carry a service live load 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:

$F'_c = 4000$ psi

$F_y = 60{,}000$ psi

Depth = 20"

$b' = 10$

Span length = 18 ft.

Solution:

Step 01:

Effective Depth

$d = 2.5$

$d = 20 - 2.5 = 17.5$

Reinforcement Ratio:

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

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

$$\rho_{max} = 0.0180$$

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Step 02:

Area of bars:

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

$A_s = \rho \times bd$

$A_s = 0.0180 \times 10'' \times 17.5'' = 3.15\ in^2$

$A_s = 3.15\ in^2$

Minimum Thikness

$h = \frac{l}{16} = \frac{18}{16} \times 12 \Rightarrow 13.5\ in$

Step 03:

Beam Self weight:

$b = 10''$

$h = 13.5''$

$$B.S.W = \frac{b \times h}{144} \times 150$$

$$= \frac{10 \times 13.5}{144} \times 150 = 140\ lb/ft$$

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

Dead load = 105 kips/ft or 1050 lb/ft

Total Dead load = 1050 + 140 = 1190 lb/ft

Now we have to find W_u:

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

$W_u = 1.2(1050 + 140) + 1.6(2470)$

$W_u = 5380\ lb/ft \Rightarrow 5.38\ kips/ft$

Required Moment = $M_u = \frac{W_u l^2}{8} = \frac{5.38 \times 18^2 \times 12}{8}$

$M_u = 2614$ in - kips

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Step 04 :

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

First we have to find "a"

$a = \frac{A_s f_y}{0.85 f'_c b} = \frac{3.15 \times 60}{0.85 \times 4 \times 10}$

$a = 5.5$

$M_n = 3.15 \times 60 \times \left(17.5 - \frac{5.5}{2} \right)$

$M_n = 2787$ in - kips

$\phi M_n = 0.9 \times 2787 = 2508$ in - kips

Now :

$M_u > \phi M_n$

$2614 > 2508$ → Doubly reinforcement required

Step 05 :

$M_{u2} = M_u - \phi M_n$

$M_{u2} = 2614 - 2508$

$M_{u2} = 106$ in - kips

Step 06 :

$M_{u2} = \phi A_s f_y (d - d')$

$A_s' = \frac{M_{u2}}{f_y (d - d')}$

$A_s' = \frac{106}{0.9 \times 60 \times (17.5 - 2.5)}$

$A_s' = 0.1308 \text{ in}^2$

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Step 07 :

Total area of Steel

$A_{ST} = A_s + A_s'$

$A_{ST} = 3.15 + 0.1308$

$A_{ST} = 3.2808 \text{ in}^2$

Step 08 :

No. of bars

(i) For A_s' Use # 2 bar

$$No = \frac{A_s'}{A_b} = \frac{0.1308}{\pi/4 \times (2/8)^2}$$

$$No = \frac{0.1308}{\pi/4 \, (2/8)^2}$$

$$= 2.66 \approx 3$$

No. of bar = 3

(ii) $A_{st} = 3.2808 \text{ in}^2$

Use # 9 bar

$$No = \frac{A_{st}}{\pi/4 \times (9/8)^2}$$

$$= \frac{3.2808}{\pi/4 \times (9/8)^2}$$

$$No = 3.2254$$

$$No = 4$$

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Step 09:

Design Moment:

$$Md = \varphi \times (Ast - As')fy(d - a/2) + As'fy(d-d') \quad -① $$

$As' = ?$

$$No = \frac{As}{Ab}$$

$As' = No \times Ab$

$As' = 2 \times \pi/4 \, (3/8)^2 = 0.098$

$Ast = ?$

$$No = \frac{Ast}{Ab}$$

$Ab \times No = Ast$

$Ast = 4 \times \pi/4 \, (9/8)^2$

$Ast = 3.97$

$$a = \frac{(Ast - As')\,fy}{0.85\,fcb}$$

$$= \frac{(3.97 - 0.098) \times 60}{0.85 \times 4 \times 10}$$

$\boxed{a = 6.83}$

put all the values in eq ①

$$Md = \varphi\,(Ast - As')\,fy\,(d - a/2) + As'fy\,(d-d')$$

$$= 0.9\left\{(3.96 - 0.098) \times 60 \times \left(17.5 - \frac{6.83}{2}\right) + (0.098 \times 60 \times (17.5 - 2.5))\right\}$$

$$= \boxed{3016.7785}$$

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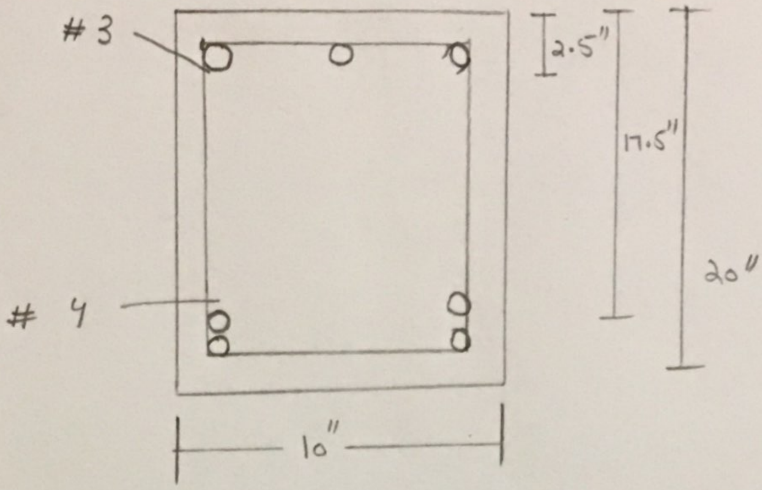

QNO 2:

(a) Briefly describe Bond stress and Development length.

Development length:

To produce the required bond strength between steel and concrete the necessary length of bar to be embedded into concrete is called development length

Bond Stress:

It is helpfull in keeping bond between concrete and reinforcement bar together. The bond stress resists the bar to come out when try to pull out the rod from hardened concrete is called bond stress.

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(b) In which conditions doubly reinforcement beam can be used?

The main condition for using doubly reinforcement beam are;

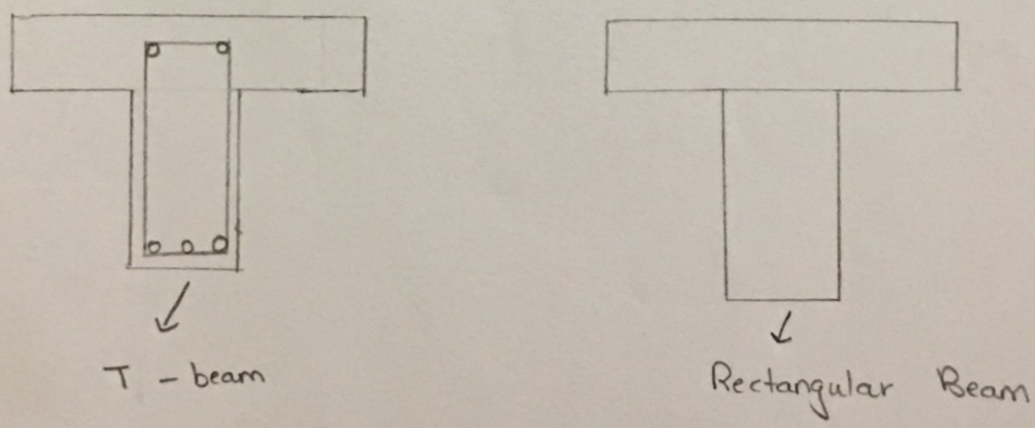
(1) Doubly reinforced beam are used for increasing the ductility of beam.

(2) Doubly reinforcement beam is prefered when simply reinforced beam is not adequate in term of moment resisting capacity.

(3) Doubly reinforcement beam is used when depth of a beam/dimension is restricted from architectural or other necessary purpose.

(4) Doubly reinforcement beam is prefered to protect or reduce deflections due to shrinkage and creep.

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



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From figure :

- both beams are T-shape, their analysis is quite different from one another.
- Slab are placed on the beam in case of rectangular beam so there is no connection between slab and beam. In this case the beam is design as a rectangular beam.
- Slab and beams are connected with each other in case of T-beam, these members acting as one member. So in this case the design are different.

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

Strength reduction factor can be used to take into account the uncertainities of material strengths, errors in the design equations, approximations in an analysis, possible variations and dimensions of the concrete sections and placement of reinforcement, the importance of members in the structures of which they are part and so on. The strength reduction factor (ϕ) are varies for the most conditions or as follows

→ 0.90 for tension control beams and slobs.

→ 0.65 or 0.70 for coloumn

→ 0.75 for shear or torsion in beams.

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

Design Methods :

- limit state Method (LSM)
- Ultimate load Method (ULM)
- Working stress Method (WSM)

① Ultimate load Method (ULM):

Method which limit the structural usefulness of the material of the structure upto ultimate load.

② Working Stress Method (WSM):

It is based on the elastic theory in which the material (steel and concrete) or assumed to be stressed well below their elastic limit under the design load.

③ limit state Method (LSM):

It is a method which limits the structural usefulness of a material of the structure upto a certain load which acceptable limit of safety and serviceability are applied. So that the failure of structure doesn't occur. It is the combination of WSM and ULM

=> In the above three methods the LSM is the best method because this method is advance over other methods, since safety & serviceability are concerned

=> In this method partial factor & safety is considered on both load and stresses.

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QNO 3:

A concrete floor system consists 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 beam webs having width b_w = 14 inch and total depth measured from the top of the slab, of h = 28 inch. The effective depth will be taken 3-inch 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 f_y = 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:

center to center distance (c/c) = 10 ft

Span length (L) = 32 ft

Slop thickness (h_f) = 6inch

width of web = b_w = 14 inch

total depth of beam = 28 inch

Effective depth of beam (d) = 28 − 3 = 25 inch

Super dead load = 50 psf

live load = 225 psf

Grade of concrete = f_c = 4psi

Grade of steel = f_y = 60,000 psi

Required:

Tensile steel area and reinforcement needed for typical member.

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Step 01:

Calculate of effective flange width (be): for T- beam

(i) $16 \times hf + bw$ (ii) $c/c \times 12$ (iii) $\frac{Span}{4} \times 12$

(iv) $\frac{CTs}{2} + btw$

(i) $16hf + bw = 16 \times 6 + 14 = 110$ inch

(ii) $c/c \times 12 = 10 \times 12 = 120$ inch

(iii) $\frac{Span}{4} = \frac{32}{4} \times 12 = 96$ inch

If c/c distance is given then there is no need for this check or condition -4 so select least value of "be" from above

so = be = 96 inch

Step 02:

check whether rectangular or T-beam analysis is required

Now we first computing moments assuming $\phi = 0.90$

$M_u = 1.2(50) + 1.6(225) = M_u = 420$ psf

$M_n = \frac{M_u}{\phi} = \frac{420}{0.90} = 466.67$ psf

$M_n = 466.67$ psf
$M_n = 5600$ psi

$M_n = 466.67 \times 12$

Trial # 01:

let $a = hf = 6''$

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

$$A_{st} = \frac{5600}{0.90 \times 60 \left(25 - \frac{6}{2}\right)} \Rightarrow A_{st} = 4.71 \text{ inch}^2$$

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Trial #02 :

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

$$a = \frac{4.71 \times 60}{0.85 \times 4 \times 96} \Rightarrow \boxed{a = 0.86 \text{ inch}}$$

$a = 0.86'' < h_f = 6''$

Rectangular beam design

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

$$A_{st} = \frac{5600}{0.90 \times 60 \times (25 - \frac{0.86}{2})} = \frac{5600}{1326.78}$$

$$\boxed{A_{st} = 4.22 \text{ inch}^2}$$

Trial # 03 :

$$a = \frac{A_s \times f_y}{0.85 \times f_c \times b_e} \Rightarrow \frac{4.22 \times 60}{0.85 \times 4 \times 96} \Rightarrow \boxed{a = 0.77 \text{ inch}}$$

$$A_{st} = \frac{M_n}{\phi \cdot f_y \times (d - a/2)} \Rightarrow \frac{5600}{0.90 \times 60 \times (25 - \frac{0.77}{2})} \Rightarrow \frac{5600}{1329.21}$$

$\boxed{A_{st} = 4.21 \text{ in}^2}$ — close enough to the previous value.

Step 03 :

Check minimum reinforcing

$$A_{st\,min} = 3\frac{\sqrt{f_c}}{f_y} \times b_w \times d = \frac{3 \times \sqrt{4000}}{60{,}000} \times 14 \times 25$$

$A_{st\,min} = 1.10 \text{ in}^2$

but not less than

$$A_{st\,min} = \frac{200\, b_w d}{f_y} = \frac{200 \times 14 \times 25}{60{,}000}$$

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$A_{st\,min} = 1.667\ in^2$

$A_{st\,min}\ 1.1667\ in^2 < 4.21\ in^2$ OK

Step 04 :

Compute the equivalent, e, value and the strain in the steel 'ε_s'

$C = \frac{a}{B_1} = \frac{0.77}{0.85} \Rightarrow c = 0.93\ in$

$\varepsilon_s = \left(\frac{d}{c} - 1\right) 0.003$

$\varepsilon_s = \left(\frac{25}{0.93} - 1\right) 0.003 \Rightarrow \varepsilon_s = 0.077$

$\varepsilon_s = 0.077 > 0.005$

steel will yield in the tension zone

Step 05 :

Compute the reinforcement, P, and check to make sure it is greater than P_{min}

$\rho = \frac{A_{st}}{bwd} = \frac{4.21}{14 \times 25} \Rightarrow P = 0.012$

$\rho_{min} = \frac{200}{fy} = \frac{200}{60{,}000} \Rightarrow 0.003$

$\rho_{min} = 0.003$ $\quad \rho > \rho_{min}$, $0.012 > 0.003$ } section works for minimum reinf

Step 06 :

selection and No of bars

let try # 10 main bars having area of one bar

$\#10 = A_b = 1.27\ in^2$

$\text{no. of bars} = \frac{A_{st}}{A_b} = \frac{4.21}{1.27} \Rightarrow 3.31 \cong 4$ bars

So take 4 # 10 main bars

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Step 07:

Design Moment

$Md = \phi f_y \times Ast\ (d - a/2)$

but first we find actual steel area (Ast) and 'a'

$Ast = 1.27 \times 4 \Rightarrow Ast = \boxed{5.08\ in^2}$

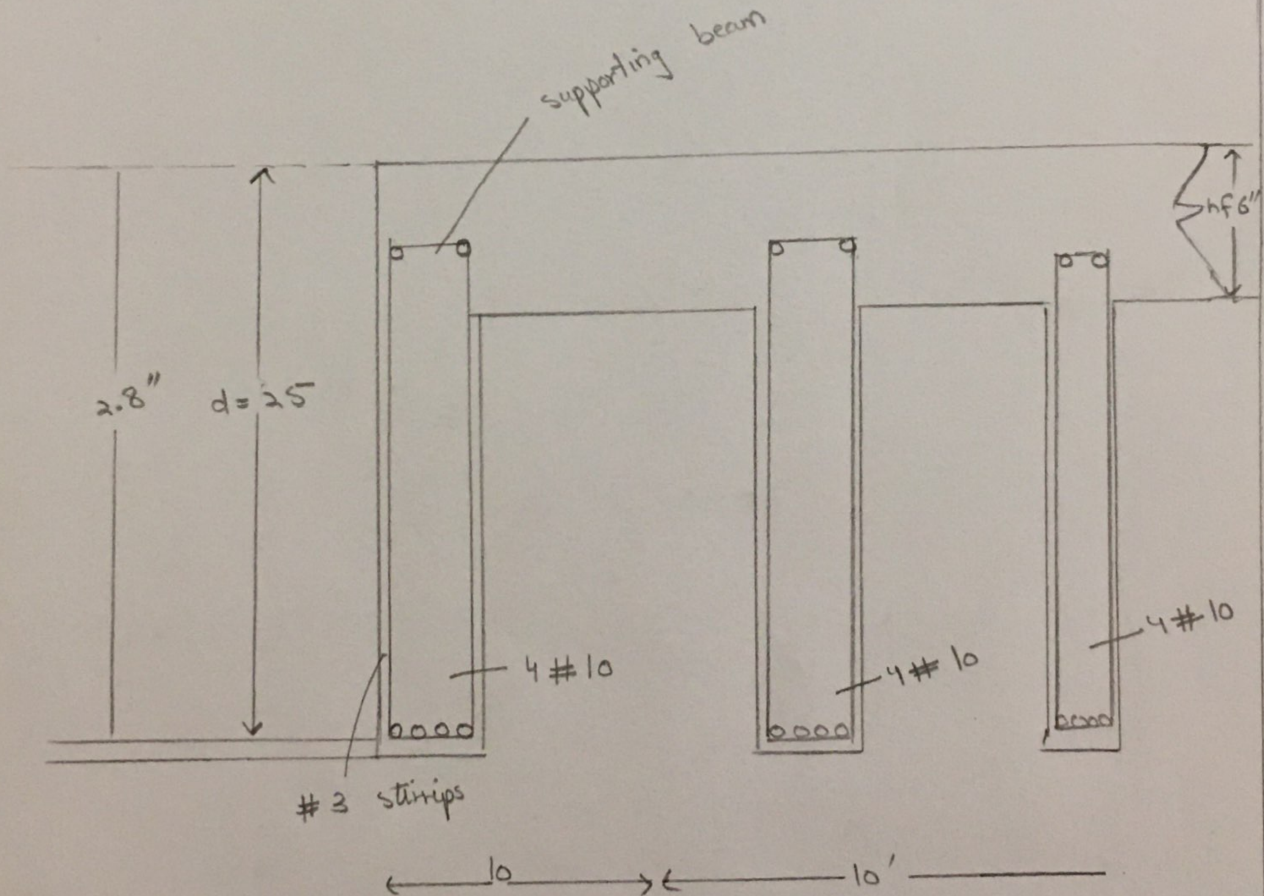
$a = \frac{Ast \times f_y}{0.85 \times f_c \times b_e} \Rightarrow \frac{5.08 \times 60}{0.85 \times 4 \times 96} \Rightarrow \boxed{a = 0.93\ in}$

$Md = \phi \times f_y \times Ast\ (d - a/2)$

$Md = 0.90 \times 60 \times 5.08\ (25 - \frac{0.93}{2}) = 6730.44\ psi$

$Md = 6730.44\ psi$

$Md > Mu \quad 6730.44 > 5600$ Design is OK.



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