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Section	B
Subject	PRCC I
Semester	6th
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Q.No1 : A rectangular beam that must carry a service load of 2.47 kips/ft (without self weight) on an 18-ft simple span is limited to inches width and 20 inches total depth for architectural reasons. if fy = 60000 psi and f'c = 4000 psi what steel area must be provided Draw sketch of your final design.

Given :- $Fy = 60\ ksi$

$Fc' = 4\ ksi$

$Fy = 60000\ psi$ $\qquad$ $w = 10''$

$Fc' = 4000\ psi$ $\qquad$ $h = 20''$

$D.L = 1.05\ k/ft$ $\qquad$ $LL = 2.47\ k/ft$

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

$d = 2.5''$

Step # 1 :- $\rho_{max} = 0.85 \times \beta \times \frac{f'c}{fy} \times \left(\frac{\varepsilon_u}{\varepsilon_u + \varepsilon_y}\right)$

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

$\rho_{max} = 0.0181$

Step # 2 :- Area of steel

$\rho_{max} = \frac{Ast}{b \times d}$

$Ast = \rho_{max} \times b \times d$

$= 0.181 \times 10 \times 17$

$= 3.077\ in^2$

Step # 03 :- Design factored moment

$$M_{u2} = \phi \times A_{st} \times f_y \times \left(d - \frac{a}{2}\right)$$

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

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

$= 5.4''$

$$M_{u2} = 0.90 \times 3.08 \times 60 \times \left(17 - \frac{5.4}{2}\right)$$

$M_{u2} = 2378.38\ k''$

Now, Moment of the given load

Beam self weight $= b \times t \times \gamma_c$

$$= \frac{10}{2} \times \frac{20}{12} \times 150$$

$= 208.33\ lb/ft$

Now, Total factored load $= 1.2\ D.L + 1.6\ D.L$

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

$= 5461.996\ lb/ft$

$= 5.46\ k/ft \approx 5461.996$

Ultimate factored moment $= \frac{wL^2}{8}$

$= \frac{5.46(18)^2}{8} \times 12$

$= 2653.56 \text{ k}''$

Thus $2378.38 < 2653.56$

It should be doubly design beam

Step # 04 :-

$M_{U_1} = M_U - M_{U_2}$

$= 2653.56 - 2378.38$

$= 275.18 \text{ k}''$

Step # 05 :-

$M_{U_1} = \phi \times A_s' \times f_y \times (d - d')$

$A_s' = \frac{M_{U_1}}{\phi \times F_y \times (d - d')}$

$= \frac{275.18}{0.90 \times 60(17 - 2.5)}$

$= 0.35 \text{ in}^2$

Step # 06 :-

$A_s = A_{st} \times A_s'$

$= 3.08 + 0.35$

$= 3.43 \text{ in}^2$

This lies in the Tension zone of steel

Step # 07

Selection of Bars for Tensile Steel ; lets Take # 6 having an area of

$$A = \frac{\pi D^2}{4} = \frac{3.14}{4}\left(\frac{9}{8}\right)^2 \Rightarrow 0.78 \times 1.266$$

$$= 0.9935 \text{ in}^2$$

$$\text{No of bar} = \frac{3.43 \text{ in}^2}{0.9935 \text{ in}^2} = 3.45 \approx 4$$

For Compression steel lets Take # 6

$$\text{Area} = 0.442 \text{ in}^2$$

$$\text{No of bar} = \frac{0.35}{0.442}$$

Step # 08 :-

$$= 0.79 \approx 1$$

Beam minimum width

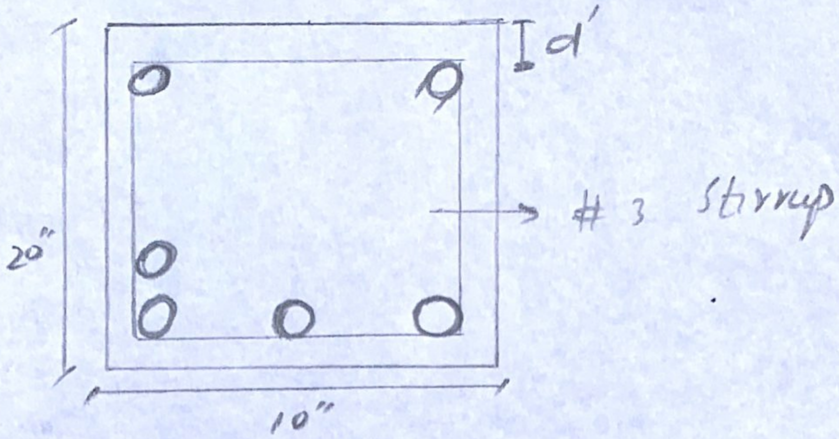
$$b_{min} = (2 \times 1.5) + 2\left(\frac{3}{8}\right) + \left(4 \times \frac{9}{8}\right) + \left(3 \times \frac{9}{8}\right)$$

$$= 3 + 0.75 + 4.5 + 3.375$$

$$11.625'' > 10''$$

It should be multiple layer

Diagram :-



$$d = 20 - 1.5 - 3/8 - 9/8 - 1/2\ (9/8)$$

$$= 20 - 1.5 - 0.375 - 1.125 - 0.5625$$

$$d = 16.44$$

$$d' = 1.5 + 3/8 + 1/2\ (6/8) = 2.25''$$

Step # 09 :- Design Moment

$$M_d = \phi \times [A_s' \times F_y \times (d - d') + (A_s - A_s') \times F_y \times (d - \frac{a}{2})$$

$$a = \frac{(A_s - A_s') \times F_y}{0.85\ F_c \times b} = \frac{(4 \times 0.994 - 1 \times 0.44) \times 60}{0.85 \times 4 \times 10}$$

$$a = 6.24$$

$$M_d = 0.90 \times [1 \times 0.442 \times 60 \times (16.44 - 2.25) + (4 \times 0.9935 - 1 \times 0.442) \times 60 \times (16.44 - \frac{6.24}{2})$$

$= 0.90 \times (376.32 + 3.532 \times 60 \times (13.32)$

$= 2879.185 > 2653.56 k''$

⇒ So the design is ok

Ques 2 :-

BOND STRESS :-

The longitudinal shear stress acting over a unit contact area between the re-inforcing bar and concrete. This is known as bond stress.

→ It is parallel to the longitudinal of the bond stress.

→ It is act on the contact surface area in the middle of the bars concrete.

Development length :-

The amount of reinforcement "bar" length needed to the embedded or projected into the column to establish the desired bond strength b/w the concrete and steel.

Reason for providing Development length :-

→ No failure due to slippage of bar occurs during the the ultimate load condition to develop a safe bond b/w the bar surface and the concrete.

→ The extra length of the bar provided as development length is responsible for transforming the stress development in any section to the adjoining sections (such as at column beam junction the extra length of bars provided from beam column).

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

→ when dimensions of the beam are restricted for architectural or structure purposes.

→ In the case of the continuous beam

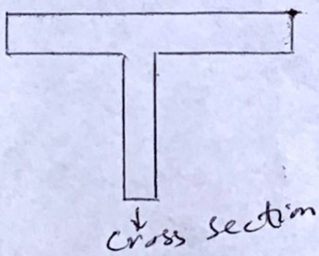
→ when the cross section of the

beam is fixed.

→ when the architecture restriction is given the following cases be used.

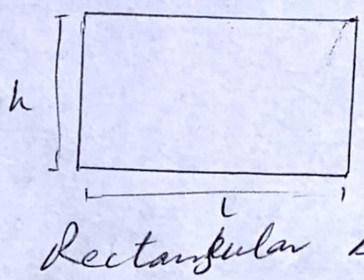
(c) Differentiate b/w T. beam analysis and rectangular beam analysis.

T- beam	Rectangular Beam
→ It is more economical	⇒ It is less economical.
→ In case of T-beam slab and beam are connected with another and act is a one member	⇒ In case of rectangular beam slab has been placed on the beam and there no connection b/w slab and beam.
⇒ It consist of T-shaped structure.	⇒ It is used generally used as compression in top fibre used and tension in bottom fibre
→ Analysis is required when $a > hf$	⇒ Analysis is required when $a \leq hf$



cross section

T- Beam



Rectangular Beam

Q2 (d)

Effect of Strength reduction Factor on Flexural Strength :-

In the design of Flexural strength the strength reduction Factor decreases from tension-Controlled section to compression controlled section to increase safety with decreasing ductility. In the reliability analysis part the (First order second moment approach) has been used to determine the Factor.

Q2 (E) Briefly describe design methods, which one of them can be best used for design of different Structural members and why?

Answer :- Three methods of structural member design. which are the following :-

(i) Working stress method.
(ii) Ultimate load method.
(iii) Limit state Method.

(i) Working Stress Method:- In this method basically assumes that the structural material behaves as a linear elastic manner, and the adequate safety can be ensured by suitably restricting the stresses in the material induced by the expected working loads on structure.

(ii) Ultimate load Method:- In this method the stress condition at the site of impending collapse of the structure is analyzed and the non-linear stress strain curves of concrete and steel are made use of.

→ The Ultimate load Method makes it possible for different types of loads to be assigned different load to be the factor under combined loading conditions.

(iii) Limit State Methods. The philosophy of the limit state method of design represents a definite advancement over the traditional design philosophies.

Sol 03 :- Given Data (13)

C/C distance = 10′ Span = 32′

hf = 6″ bw = 14″ h = 28″

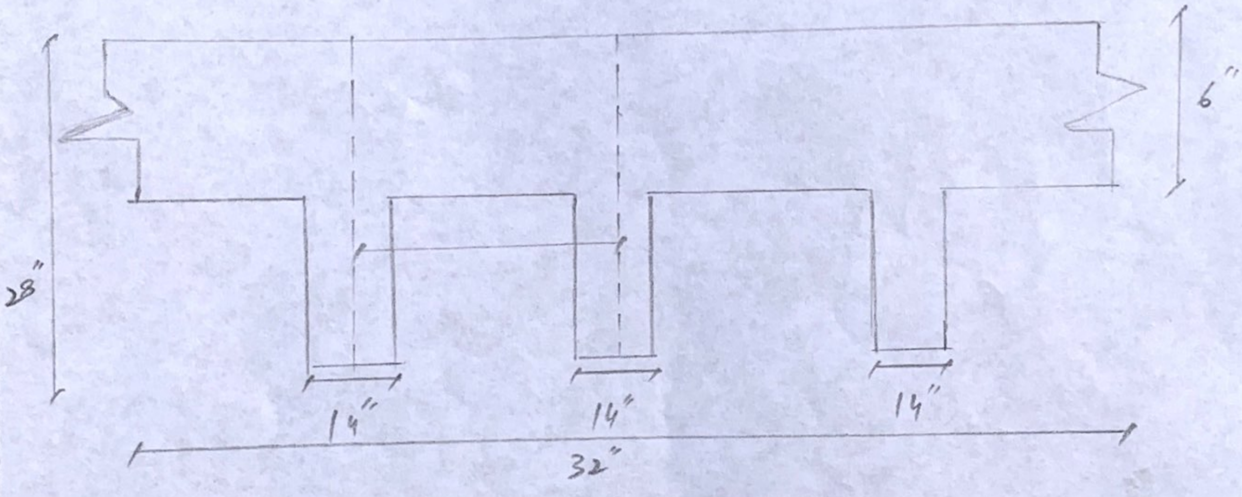
d = Effective depth = h - 3

= 28 - 3 = 25″

D.L = 50 lb/ft² L.L = 225 lb/ft²

FY = 60,000 psi = 60 ksi

F′c = 4000 psi = 4 ksi



Step # 01 :- Ultimate factored moment

$$MU = \frac{wL^2}{8}$$

(i) Self weight of the beam

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

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

$= 408.33$ lb/ft

∴ Pcc = 140 lb/ft

Rcc = 150 lb/ft

(ii) Total factored load

$= 1.2\,DL + 1.6\,LL$

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

$= 909.99\ lb/ft$

$= 0.909\ k/ft$

$MU = 0.909 \times (32)^2 = 116.352 \times 12$

$= 1396.224\ k/ft$

Step # 02:- Determine the effective width "be"

1- $16 \times hf + bw = 16 \times 16 + 14 = 110''$

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

3- Span 14 $= \frac{32}{4} \times 12 = 96''$

Select at least value of be i.e 96

Step # 03:- Check weather Rectangular or - T-beam analysis is required

Trial 1:- let a hf = 6"

$$Ast = \frac{MU}{\phi \times Fy \times d\,(d - \frac{a}{2})}$$

$$= \frac{1396.244}{0.90 \times 60 \times (25 - \frac{6}{2})} = 1.75\ in^2$$

Trial # 02 :-

$$a = \frac{Ast \times Fy}{0.85\ Fc' \times be} = \frac{1.75 \times 60}{0.85 \times 4 \times 96}$$

$$= 0.22'' < 6''$$

Thus Rectangular beam analysis is required

$$Ast = \frac{MU}{\phi \times Fy \times (d - \frac{a}{2})} = \frac{1396.244}{0.90 \times 60 \times (25 - \frac{0.2}{2})}$$

$$= 1.04\ in^2$$

Trial # 03 :-

$$a = \frac{1.04 \times 60}{0.85 \times 4 \times 96} = 0.19''$$

$$Ast = \frac{1396.244}{0.90 \times 60\ (25 - \frac{0.19}{2})}$$

$$= 1.04\ in^2$$

Step # 04 :-

$$\rightarrow \rho_{max} = 0.85 \times \beta \times \frac{Fc'}{Fy} \times \left(\frac{\varepsilon_u}{\varepsilon_u + \varepsilon_t}\right)$$

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

$$\rho_{max} = 0.018$$

$$\rho_{min} = \frac{200}{Fy} = \frac{200}{60000} = 0.003$$

$$\rho = \frac{Ast}{b \times d} = \frac{1.03}{14 \times 25} = 0.0029$$

$$\rho_{min} < \rho < \rho_{max}$$

$$0.003 < 0.002 < 0.018$$

As ρ is less than ρ_{min} so

$$\rho = \frac{Ast}{b \times d}, \quad \therefore Ast = \rho_{min} \times b \times d$$

$$= 0.003 \times 14 \times 25$$

$$= 1.05 \text{ in}^2$$

Step # 05 :-

Select no of bars

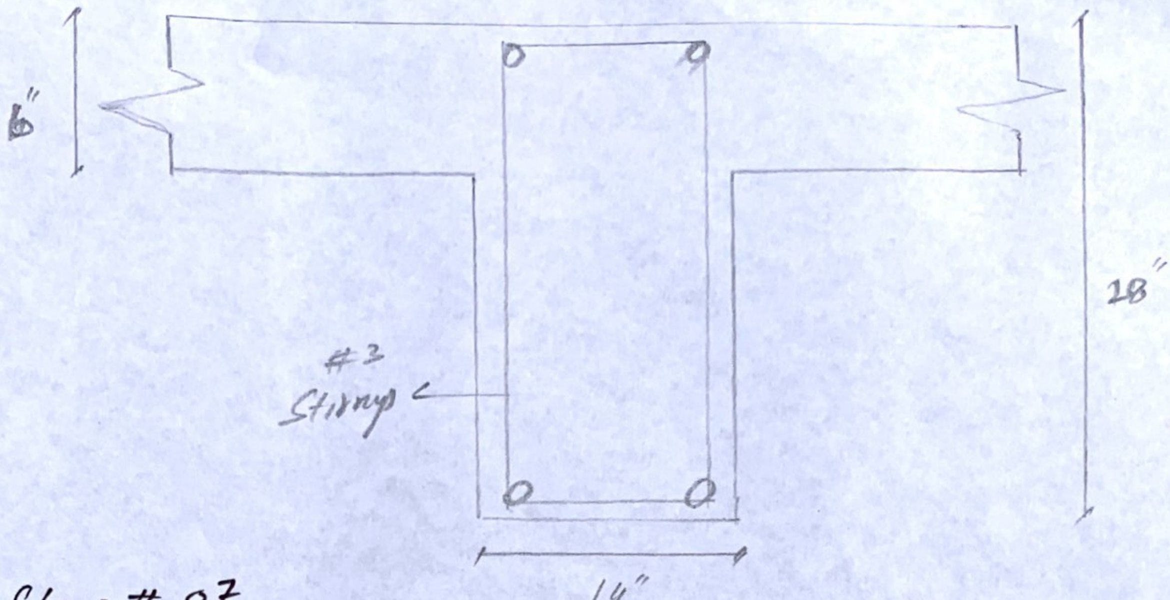
Using # 10 bar having Area 1.27 in^2

$$\text{No of bars} = \frac{Ast}{Ab} = \frac{1.05}{1.27} \approx 2 \text{ bars}$$

Step # 06 :-

Check on minimum width

$$b_{min} = (2 \times 1.5) + (2 \times 3/8) + 2(10/8) + 1 \times (10/8) = 7.5'' < 14''$$



Step # 07

Design Method

$$Md = \phi \times Fy \times Ast \times \left(d - \frac{a}{2}\right)$$

→ $Ast = 1.27 \times 2 = 2.54 \ in^2$

→ $a = \frac{Ast \times Fy}{0.85 \times Fc' \times be} = \frac{2.54 \times 60}{0.85 \times 4 \times 96}$

$= 0.467"$

$$Md = 0.90 \times 60 \times 2.54 \times \left(25 - \frac{0.467}{2}\right)$$

⇒ 3396.97

3396.97 > 1396244

Design is Correct.