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SUBMITTED TO : ENGR. FAWAD KHAN

SUBJECT : PLAIN & REINFORCED CONCRETE - 1

SECTION : B

MODULE : 6th

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1. A rectangular beam that must carry a service load of 2.47 K/ft and a calculated dead load of 1.05 K/ft (without selfweight) on an 18 ft simple span is limited to 10" width and 20" total depth for architectural reasons. If $f_y = 60000 psi$ and $f'_c = 4000 psi$. What steel area must be provided? Draw sketch of your final design?

Sol: Given data :

Width (b) = 10" ; $d = h - 3$

Height (h) = 20" ; $d = 20 - 3 = 17"$

Dead Load = 1.05 K/ft ; $d' = 2.5"$

Live Load = 2.47 K/ft

$f'_c = 4000 psi = 4 ksi$

$f_y = 60000 psi = 60 ksi$

Step01: Check the capacity of section as singly reinf. beam.

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

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

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

Step 02: Determine Area of the steel.

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

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

$$A_{ST} = 0.0181 \times 10 \times 17$$

$$\boxed{A_{ST} = 3.08\ in^2}$$

Step 03: Design factored moment

$$M_{U_2} = \phi \times A_{ST} \times f_y \times \left(d - \frac{a}{2}\right) \quad ; \quad a = \frac{A_{ST} \times f_y}{0.85 \times f'_c \times b}$$

$$= 0.90 \times 3.08 \times 60 \times \left(17 - \frac{5.4}{2}\right) \qquad = \frac{3.08 \times 60}{0.85 \times 4 \times 10}$$

$$\boxed{M_{U_2} = 2378.38\ K''} \qquad = 5.4''$$

Moment due to given load:

$$\text{Beam self weight} = b \times t \times \gamma_c$$

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

$$= 208.33\ lb/ft$$

$\because \gamma_c$
For PCC = 140 lb/ft^3
For RCC = 150 lb/ft^3

Now,

$$\text{Total Factored load} = 1.2 D.L + 1.6 L.L$$

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

$$= 5461.96\ lb/ft = 5.46\ K/ft$$

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

$$M_u = \frac{5.46\,(18)^2}{8} \times 12 = 2653.56\,k''$$

Thus; $2378.38 < 2653.56$

Doubly Reinforced beam is required.

Step 04: Determine "M_{u1}"

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

$$= 2653.56 - 2378.38$$

$$\boxed{M_{u1} = 275.18\,k''}$$

Step 05: Determine "A_s'"

$$M_{u1} = \phi \times A_s' \times f_y \times (d - d')$$

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

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

$$\boxed{A_s' = 0.35\,in^2}$$

Scanned with CamScanner

Step 06: Determine the Total Area.

$$A_s = A_{ST} + A_s'$$
$$= 3.08 + 0.35$$
$$A_s = 3.43\ in^2$$

- This reinforcement lies in the tension zone of beam. steel

Step 07: Selection of Bars

A- For Tensile steel; let's take #7 which is having area of $0.60 in^2$

$$\text{No of bars} = \frac{\text{Area of steel}}{\text{Area of bar}} = \frac{A_s}{A_b}$$
$$= \frac{3.43}{0.60} = 5.72 \approx 6\ \text{bars}$$

B- For Compression steel; let's take #5 having an area of $0.31 in^2$

$$\text{No of bars} = \frac{\text{Area of steel}}{\text{Area of bar}} = \frac{A_s'}{A_b}$$
$$= \frac{0.35}{0.31} = 1.13 \approx 2\ \text{bars}$$

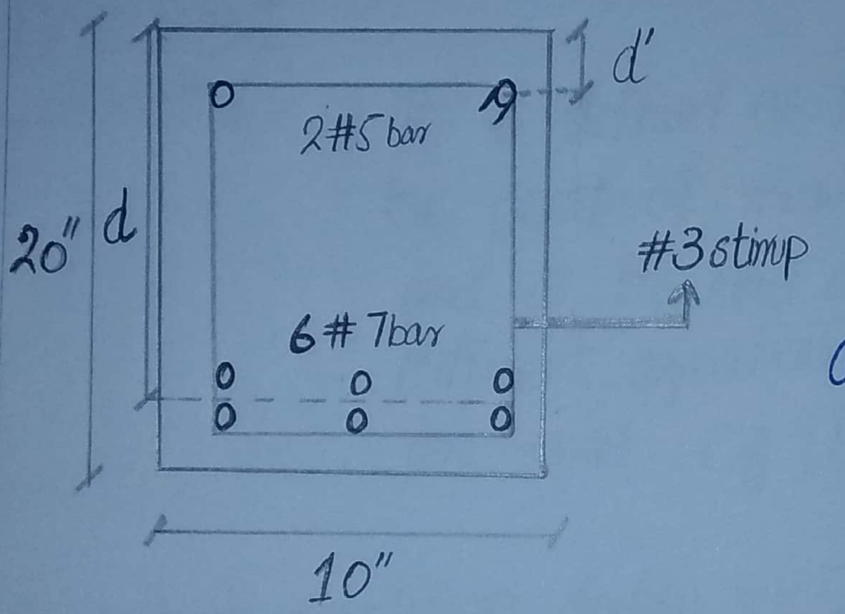
Step 08: Check on minimum width of beam.

$b_{min} = (2 \times C.C) + 2 \times$ dia of stirrup + (No of Main bars × dia of M.bar) + No of spaces b/w main bar × dia of M.bar.

$$b_{min} = (2 \times 1.5) + 2\left(\frac{3}{8}\right) + \left(6 \times \frac{7}{8}\right) + \left(5 \times \frac{7}{8}\right)$$

$$b_{min} = 13.375''$$

As $13.375'' > 10''$
so reinforcement should be provided in multiple layers.



$$d = 20 - 1.5 - \frac{3}{8} - \frac{7}{8} - \frac{1}{2}\left(\frac{7}{8}\right)$$

$$d = 16.8125''$$

$$d' = 1.5 + \frac{3}{8} + \frac{1}{2}\left(\frac{5}{8}\right)$$

$$d' = 2.1875''$$

Step 09: Design Moment.

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

$$a = \frac{(A_s - A_s') \times f_y}{0.85 \times f_c' \times b} = \frac{(6 \times 0.60 - 2 \times 0.31) \times 60}{0.85 \times 4 \times 10}$$

$$a = 5.26''$$

$$M_d = 0.90\left[(2 \times 0.31) \times 60 \times (16.8125 - 2.1875) + (6 \times 0.60 - 2 \times 0.31) \times 60 \times \left(16.8125 - \frac{5.26}{2}\right)\right]$$

$$M_d = 2771.89\ k''$$

$2771.89k'' > 2653.56k''$

DESIGN IS OK!

2.
a) Briefly describe Bond stress and Development length.

Ans: BOND STRESS: The pulling out of steel bar from concrete is resisted by gripping action of concrete is known as bond and the resulting stress is called bond stress.

DEVELOPMENT LENGTH: It is defined as the necessary length b/w the point of maximum stress in a bar and at the end of bar. For different bars different equations of development lengths are used. e.g For #14 bar; $L_d = \frac{0.085 + f_y}{\sqrt{f'_c}}$

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

Ans. When there are some architectural or aethetic restrictions so we use doubly reinforced beam.

- Major reason for providing doubly reinforced beam is to ensure there is increase in moment carrying capacity, ensure safety against reversal of stresses in the structure due to wind forces, seismic forces and temperature stresses.

P.T.O

c. Differentiate between T-beam analysis and Rectangular beam?

Ans:

T-BEAM	RECTANGULAR-BEAM
• It has **different** geometry with more moment of inertia comparitivly.	• Comparitively less moment of inertia.
• **Flexural** capacity of **T**-beam varies based on the sign of moment.	• Flexural capacity depends on the location of reinforcement to yield.
• Design procedure depends on the location of moment.	• Simple design; no complexion.

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

Ans: **In** the design of flexural strengths, the strength reduction factor (ϕ) decreases from tension-controlled sections to compression-controlled sections to increase safety with decreasing ductility. The tension-controlled sections are desirable for their ductile behaviour for giving sufficient warning **p**rior to failure. Depending on the structure compression-controlled sections have less ductility thus they act simultaneously to hold togather the structure.

P.T.O

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

Ans: Following are the design methods of PRC:

i- Elastic Method of Design OR WSM:

It is defined as the method which limits the structural usefulness of the material of the structure upto certain load at which the min. stress in extreme fiber reaches the characteristic strength of material in bending.

ii- Ultimate Load Design Method:

It is defined as a method which limits the structural usefulness of material of the structure upto ultimate load.

iii Limit state method:

It is defined as a method which limits the structural usefulness of material of structure upto certain load at which acceptable limit of serviceability and safety are applied so that failure of the structure doesnot happen.

→ Limit state method can be used because partial factor of safety is considered on both loads & stresses. This method is advance over other methods since safety and serviceability are considered.

3. A concrete floor system consists of parallel T beams spaced 10ft on centers and spanning 32ft between supports. The 6inch thick slab is cast monolithically with T-beam webs having width $b_w = 14''$ 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 it's own weight, each beam must carry a superimposed D.L of 50psf and S.L = 225psf. Material strengths are $f_y = 60,000$ psi & $f'_c = 4000$psi. Determine the required tensile steel area & select the reinforcement needed for a typical member. Draw sketch of your final design.

Sol: Given data:

C/C distance = 10'

Span = 32'

$h_f = 6''$

$b_w = 14''$

$h = 28''$

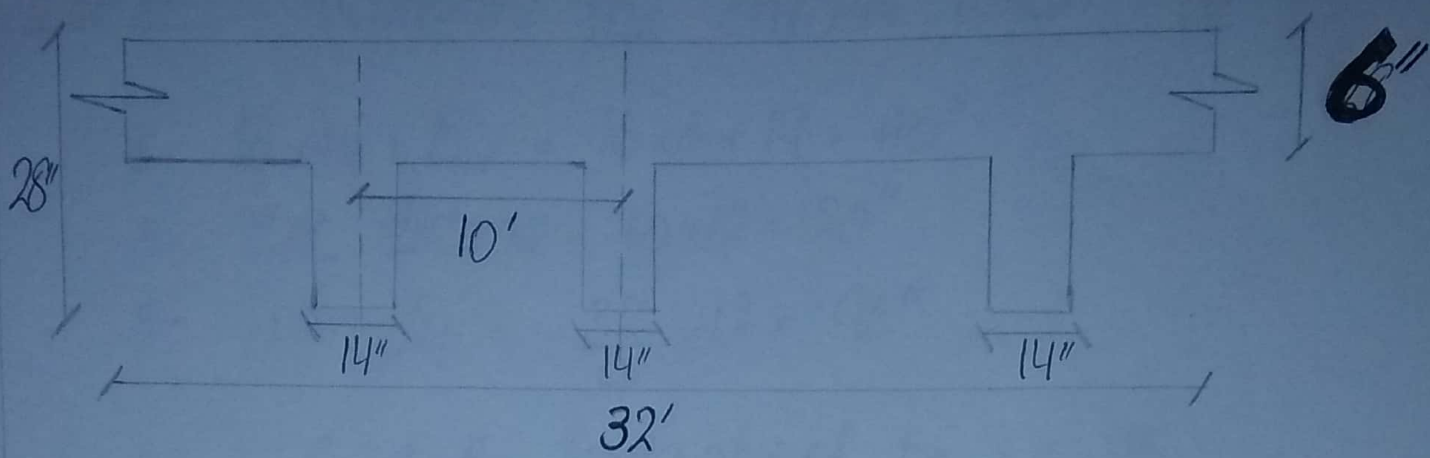
d = Effective depth = $h - 3 = 28 - 3 = 25''$

D.L = 50 lb/ft^2

L.L = 225 lb/ft^2

$f_y = 60,000$ psi = 60ksi

$f'_c = 4000$psi = 4ksi



Step 01: Ultimate factored moment.

$$M_u = \frac{WL^2}{8}$$

i- Self weight of the beam

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

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

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

∴ γ_c
For PCC = 140 lb/ft
For RCC = 150 lb/ft

ii- Total factored load

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

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

$$= 909.99 \text{ lb/ft}$$

$$= 0.909 \text{ K/ft}$$

$$M_u = \frac{0.909 \times (32^2)}{8} = 116.352 \times 12 = 1396.224 \text{ K-in}$$

Step 02: Determine the Effective width "be".

1- $16 \times h_f + b_w = 16 \times 6 + 14 = 110''$

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

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

Select the least value of be i.e 96.

Step 03: Check whether Rectangular or T-beam analysis is required.

Trial #1:

Let $a = h_f = 6''$

$$A_{ST} = \frac{M_u}{\phi \times f_y \times (d - a/2)} = \frac{1396.244}{0.90 \times 60 \times (25 - 6/2)}$$

$$A_{ST} = 1.175 in^2$$

Trial #2:

$$a = \frac{A_{ST} \times f_y}{0.85 f_c \times b_e} = \frac{1.175 \times 60}{0.85 \times 4 \times 96}$$

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

Thus Rectangular beam analysis is required.

$$A_{ST} = \frac{M_u}{\phi \times f_y \times (d - a/2)} = \frac{1396.244}{0.90 \times 60 \times (25 - \frac{0.2}{2})}$$

$$= 1.04 in^2$$

Trial #3:

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

$$A_{ST} = \frac{1396.244}{0.90 \times 60 \times (25 - 0.19/2)} = 1.04 in^2$$

→ Same Area.

Step 04: Check ρ_{max} and ρ_{min}.

$$\star \ \rho_{max} = 0.85 \times \beta \times \frac{f'c}{fy} \times \left(\frac{\varepsilon_U}{\varepsilon_U + \varepsilon_t}\right)$$

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

$$\rho_{max} = 0.018$$

$$\star \ \rho_{min} = \frac{200}{fy} = \frac{200}{60000} = 0.003$$

$$\star \ \rho = \frac{A_{ST}}{b \times d} = \frac{1.03}{14 \times 25} = 0.0029$$

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

$$0.003 < 0.002 < 0.018$$

As ρ is less than ρ_{min} Thus;

$$\rho = \frac{A_{ST}}{b \times d}; \ A_{ST} = \rho_{min} \times b \times d$$

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

$$= 1.05 in^2$$

Step 05: Selection and No. of bars.

Let's use #10 bar having area of $1.27 in^2$

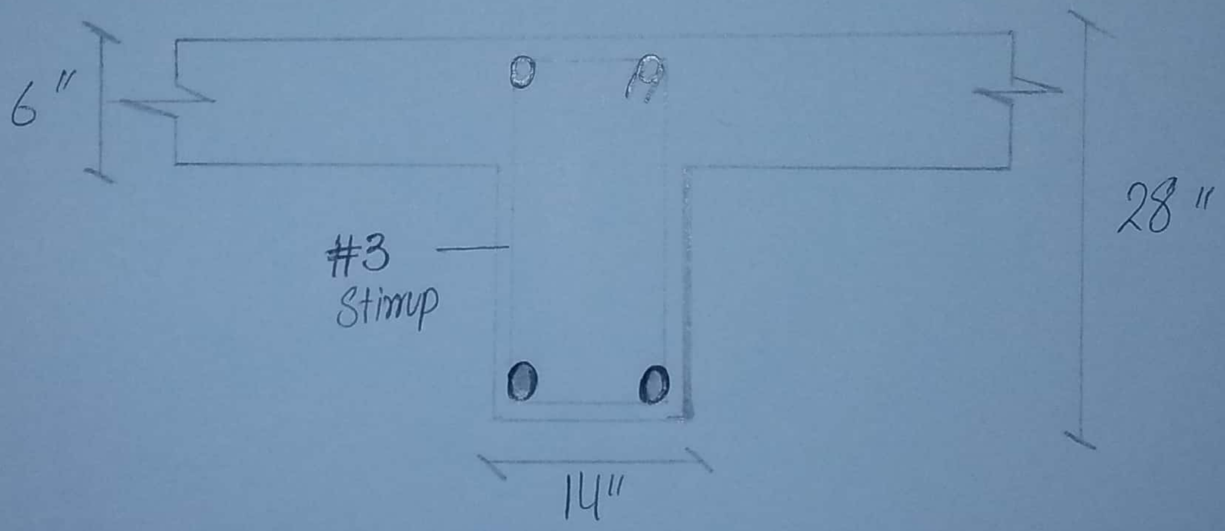
$$\text{No of bars} = \frac{A_{ST}}{A_b} = \frac{1.05}{1.27} \approx 2 \text{ bars}$$

Step 06: Check on minimum width

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

$$= 7.5'' < 14''$$

It is good in one layer.



Step 07: Design Moment.

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

* $A_{ST} = 1.27 \times 2 = 2.54 in^2$
* $a = \frac{A_{ST} \times f_y}{0.85 f'_c \times b_e} = \frac{2.54 \times 60}{0.85 \times 4 \times 96} = 0.467''$

$\rightarrow M_d = 0.90 \times 60 \times 2.54 \times \left(25 - \frac{0.467}{2}\right) = 3396.97$

$\Rightarrow 3396.97 > 1396.244$ DESIGN IS OK!