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Subject "P.R.C. Design 1"

Semester 6th

Section B

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Q:No:01:-

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 $f_y = 60000$ psi and $f'_c = 4000$ psi. What steel area must be provided? Draw sketch of your final design.

Sol:

Given Data:

$f_y = 60000$ psi

$f'_c = 4000$ psi

$d = h - 3$

$d = 20 - 3 = 17''$

$d = 17''$

$W = 10''$

$h = 20''$

$D.L = 1.05$ k/ft

$L.L = 2.47$ k/ft

$d' = 2.5''$

Step:01:

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

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

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$$\rho_{max} = 0.0181$$

Step:02

Area of steel

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

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

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

$$A_{ST} = 3.077 \, in^2$$

Step:03:

Design factored moment.

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

$$a = \frac{A_{ST} \times f_y}{0.85 f_c' b}$$

$$a = \frac{3.08 \times 60}{0.85 \times 4 \times 10} = 5.4''$$

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

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

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Now

Moment of the given load

Beam self weight = b × h × γc

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

$= 208.33$ lb/ft

Now:

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

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

$= 5461.996$ lb/ft

$= 5.46$ K/ft

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

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

$= 2653.56$ k"

Thus $2378.38 < 2653.56$

it should be doubly designed beam

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Step:04:

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

$$= 2653.56 - 2378.38$$

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

Step:05:

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

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

$$= \frac{275.18}{0.90 \times 60 (17.25)}$$

$$= 0.35 \, in^2$$

Step:06:

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

$$= 3.08 + 0.35$$

$$A_s = 3.43 \, in^2$$

This lies in the tension zone of steel.

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Step:07: Selection the bars

For tensile steel, Let's take #8 having an area of 0.785 in²

$$\text{No of bars} = \frac{A_s}{A_b} = \frac{3.43}{0.785} = 4.36 \approx 5 \text{ bar}$$

For compression steel; lets take #6 having an area of 0.4412 in²

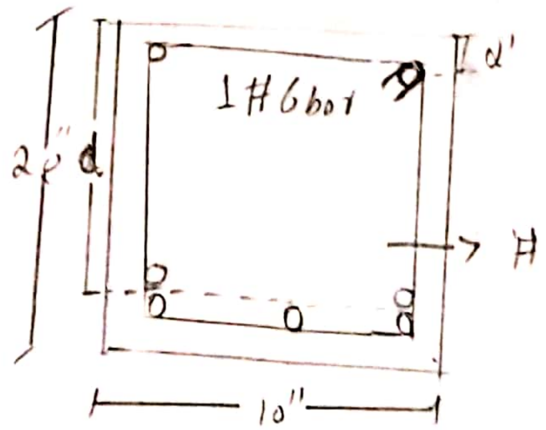
$$\text{No of bars} = \frac{A_s'}{A_b} = \frac{0.35}{0.4412} = 0.79 \text{ bars} \approx 1 \text{ bar}$$

Step:08: Beam minimum width

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

$$= 12.75'' > 10''$$

It should be in multiple layers



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

$$d = 16.625''$$

$d' = 1.5 + \frac{3}{8} + \frac{1}{8}(6/8) = 2.25''$

$$d' = 2.25''$$

Step: 09:

Design moment:

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

$a = \frac{(A_s - A_s') \times f_y}{0.85 f_c \times b} = \frac{(5 \times 0.785 - 1 \times 0.441)}{0.85 \times 4 \times 10}$

$$a = 6.15''$$

$M_d = 0.90 \times \left[1 \times 0.441 \times 60 \times (16.625 - 2.25) + (5 \times 0.785 - 1 \times 0.441) \times 60 \times \left(16.625 - \frac{6.15}{2}\right)\right]$

$M_d = 2891.5245$

$M_d = 2891.5245 > 2653.56k''$

Design is ok

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Q:No:02

Part:01: Briefly describe Bond Stress and Development Length.

Ans: **BOND Stress:**

The stress which is acting on the outer interface of steel to the surrounding concrete is called bond stress. This stress helps in keeping bond between reinforcement and concrete together. Bond stress resists any force that tries to pull out the rods from the concrete.

- When you try to pull out the reinforcement bar from hardened concrete, then this bond stress resists the bar to come out.
- Different grades of concrete has different bond stress.

Classification of Bond stress:

→Bond stress are classified into the following types.

- Anchorage bond.
- Flexular bond

Development Length:

The amount of reinforcement length needed to be embedded or projected into the column to established the desired bond strength between the concrete and steel is known as development length.

Q:-No:-02

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

Ans:- Doubly reinforced beam can be used due to the following reasons or conditions.

- When the dimensions of the beam are restricted due to any constraints like availability of head room, architectural consideration and the moment of resistance of singly reinforced section is less than the external moment.
- When the external loads may occur on either face of the member i-e the loads are alternating and may cause tension on both forces of the member.

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- When the loads are ecentric
- In case of continous beam or slab the sections at supports are generally designed as doubly reinforced beam.
- When a beam is subjected to accidental or sudden lateral load.

Q:No:02

Part:C: **Difference between T-beam analysis and rectangular beam analysis.**

Ans:

Rectangular beam:

In case of rectangular beam, slab has been placed on the beam so there is no connection between slab and beam

- Most commonly used beam and has cross section in the shape of a rectangular of specific breadth (b) and depth (d). The ratio of b/d is limited based upon the code of practice.

T-Beam: In case of T-Beam, slab and beam are connected with one another and acts as a one member

- This beam was developed and effectively used to reduced the cost of construction by floring beams along with the slab during concrete. It has two major zones. the flange and the web.

Q:-No:- 02

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

Ans:- In the design of flexural strength the strength reduction factor ϕ decrease from tension controlled sections to compression controlled sections to increase safety with decreasing ductility. This paper presents how to determine the reduction factor for flexural strength of reinforced concrete beam according to ACI code. In the reliability - ~~strength~~ based design the reliable prediction of the flexural strength of reinforced concrete members is assused by the use of reduction factor corresponding to different target reliability index β. In this study for different β and coefficient of variation of the flexural strength parameter. the flexural strength reduction factor has been investigated by using experimental studies.

Q: No: 02

Part e: Briefly describe design methods, which one of them can be best used for design of different structural member and why?

Ans: Design method:

There are three methods of structural design i.e working stress, limit state and ultimate load method of structural design. These design method are used for reinforced concrete as well as steel structure design.

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Working Stress method:

It is based on the linear theory (elastic theory) The stresses in the materials which are developed due to working load are restricted given a safe design.

- The assumptions in working stress method of design as:

1. The steel and concrete behaves as linear elastic material.
2. The design is carried out by the factored of safety of 3 for concrete cube strength and a factor of safety 1.8 for yield strength of steel.

Ultimate load method:

This method is otherwise known as load factor method or ultimate strength method. This method is based on the ultimate strength when the design member would fail. In this method factored are taken into account only on load factors and the method of ultimate design of a structure is designed as a method which limits the structural usefulness of the material of the structure ulto ultimate load.

Limit load method:

Limit state refers to the acceptable limit for safety and serviceability of structure before the failure of structure.

=> Limit state method can be best use of design of different structural member because it helps to design structure based on both safety and serviceblity. The structure are design to with stand ultimate load or the loads at which failure occurs unlike working stress method where only service loads are considered This loads to enhanced safety.

Q:No:03:

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 bw = 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 strength are fy = 60000 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.

Sol:

Given Data:

c/c distance = 10'

span = 32'

$h_f = 6''$

$b_w = 14''$

$h = 28''$

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

$D.L = 50 \ lb/ft^2$

$L.L = 225 \ lb/ft^2$

$f_y = 60000 \ psi = 60 \ ksi$ / $f'_c = 4000 \ psi = 4 \ ksi$

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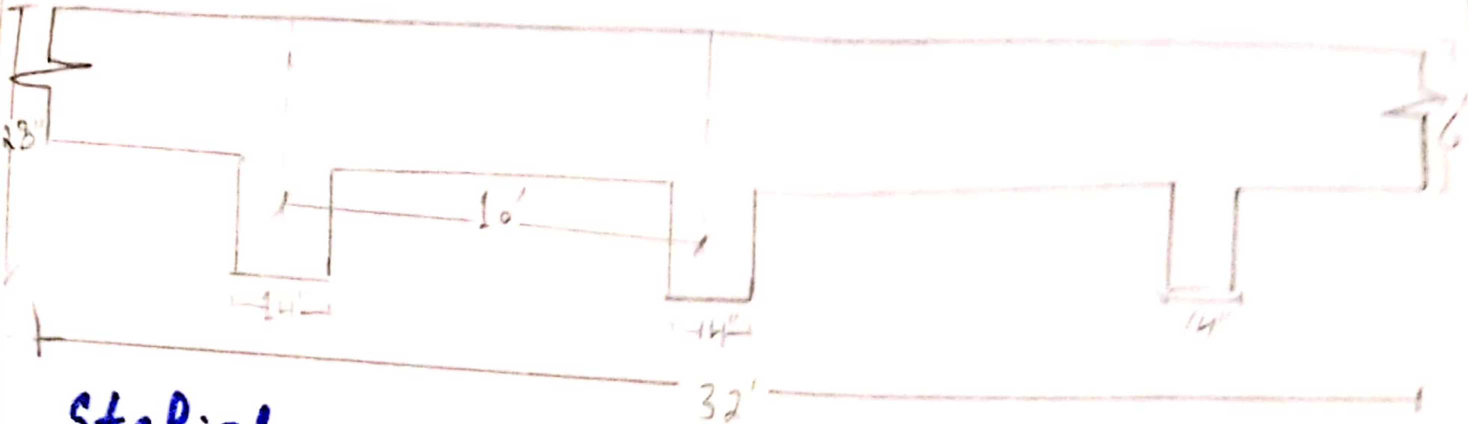

Step:01:

ultimate factored moment.

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

i- self weight of the beam

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

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

$\boxed{W_t = 408.33\ lb/ft}$

∴ $\gamma_{cc} = 140\ lb/ft$

$R_{cc} = 150\ lb/ft$

(ii) Total factored load

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

$= 1.2(50 + 408.32) + 1.6(225)$

$= 909.99\ lb/ft$

$= \boxed{0.909\ k/ft}$

$M_u = \frac{0.909 \times (32^2)}{8} = 116.352 \times 12 = 1396.224\ k/ft$

Step:02: Determine the Effective width "be"

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

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

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

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select the least value of be i.e 96.

Step:03:

Check whether rectangular or T-beam analysis is required.

Trial #1:

Let $a = h_f = 6''$

$$A_{ST} = \frac{M_u}{\phi \times f_y \times (d - a/2)} = \frac{1396.2441}{0.90 \times 60 \times (25 - 6/2)}$$

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

Trial #02:

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

$a = 0.22'' < 6''$

Thus Rectangular beam analysis is required

$$A_{ST} = \frac{M_u}{\phi \times f_y \times (d - a/2)} = \frac{1396.2441}{0.90 \times 60 \times (25 - \frac{0.2}{2})}$$

$$\boxed{A_{ST} = 1.04\ in^2}$$

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Trial#03:

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

$$A_{ST} = \frac{1396.2441}{0.90 \times 60 \times (25 - 0.19/2)} = 1.04\,in^2$$

$A_{ST} = 1.04\,in^2$
→ Same Area

Step04: Check ρ_{max} and ρ_{min}

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

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

$\rho_{max} = 0.018$

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

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

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

$$0.003 < 0.002 < 0.018$$

As ρ is less than ρ_{min} Thus;

$\rho = \frac{A_{ST}}{b \times d}$, $A_{ST} = \rho_{min} \times b \times d = 0.003 \times 14 \times 25$

$A_{ST} = 1.05\,in^2$

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Step:05: Selection and No of bars

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

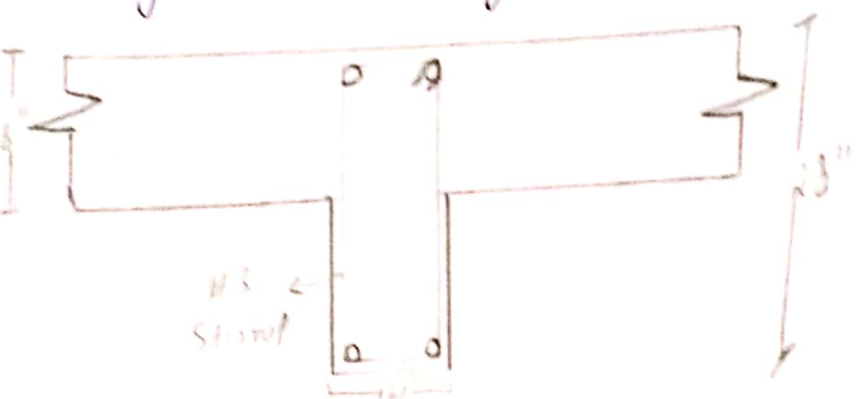
$$\text{No of bars} = \frac{A_{st}}{A_b} = \frac{1.08}{1.27} \approx 2 \text{ bars}$$

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.

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

$$* \ A_{ST} = 1.27 \times 2 = \boxed{2.54\ in^2}$$

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

$$\boxed{a = 0.467''}$$

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

$$\boxed{M_d = 3396.97}$$

$$\Rightarrow 3396.97 > 1396.244$$

Design is ok!

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