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Section # A

Subject # PRC Design -1

Samester # 6th

Department # Civil Engineering

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Exam # Mid-Term

Q1 A rectangular beam that must carry a service live load of 2.47 kips/ft. and a calculated dead load of 1.05 kips (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?

Given data:-

From Question

Required data:-

Dead load = 1.05 kips/ft

Live load = 2.47 kips/ft

Width (b) = 10"

Span = 18'

Height (h) = 20"

f'_c = 4000 psi = 4 ksi

f_y = 60,000 psi = 60 ksi

Solution:-

Step #1 First of all calculate effective depth (d) [redacted] [redacted].

Effective depth (d) = h - 3

= 20 - 3

= 17"

Effective Cover (d') = 2.5"

Reinforcement Ratio:-

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

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

$$\rho_{max} = 0.0180625$$

Step# 2

Now we are going to Find the Area of Steel

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

$$A_{st} = 0.0180 \times (10 \times 17)$$

$$= 3.06 \text{ in}^2$$

Step#3

By formula of design Moment

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

$$a = \frac{A_{st} \times f_y}{0.85 \times f'_c \times b} = \frac{3.06 \times 60}{0.85 \times 4 \times 10} = 5.4''$$

$$M_{u_2} = 0.90 \times 3.06 \times 60 \times (17 - 5.4/2)$$

$$= 2362.93 \text{ Kip-inch}$$

Moment due to given Load

$$\text{Beam weight} = 10/12\,(20/12)\,(150)$$

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

Total Factor Load:- $1.2\,(1050 + 208.33) + 1.6\,(2470)$

$= 5461.99$ lb/ft

$= 5.46$ kips/ft

Ultimate Factored Moment: $\dfrac{WL^2}{8}$

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

$M_u = 2653.56$

Now:-

$M_{u2} < M_u$

$2362.92 < 2653.56$

↓

Doubly Reinforcement Required

Step#4

$M_{u1} = 2653.56 - 2362.92$

$= 290.64$ kip-inch

Step# 5

Compression zone of steel Area will be.

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

$A_{st}' = \dfrac{M_{u1}}{\phi \times f_y \times (d - d')}$

$= \dfrac{290.64}{0.90 \times 60 \times (17 - 2.5)} =$ **$0.37\ in^2$**

Step#6

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

$= 3.06 + 0.37 =$ **$3.43\ in^2$**

Step#7 As we know that

we use #8 bars, (dia 8/8 = 1")

Area = $0.785 in^2$

No. of bars = $\frac{Ast}{\text{Area of 1 bar}}$

$= \frac{3.43}{0.785} = 4.36 \Rightarrow 5$ bars

So 5 #8 bars
For Tensile zone

Compression Steel:-

Use #6 bars

dia (6/8) = 0.75" , Area $0.44 in^2$

No of bars = Ast = $\frac{0.37}{0.44} = 0.84$

$= 0.84 \approx 1$ bar

So 1 #6 bars in → compression zone

Step # 8 Beam Minimum Width

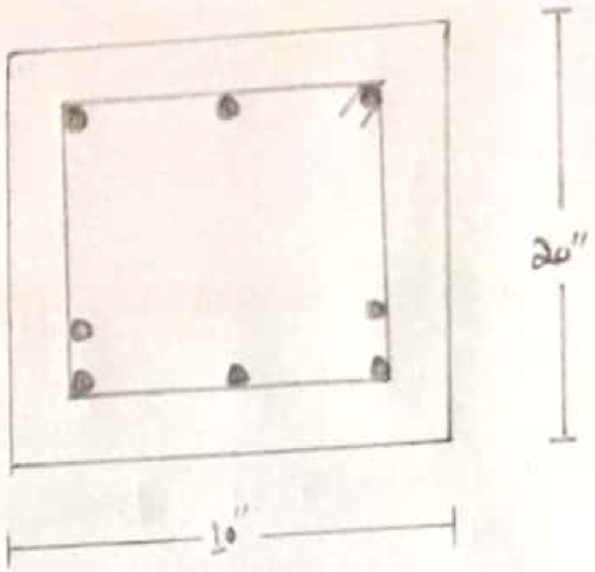
$b_{min} = 2(1.5) + 2(3/8) + 5(8/8) + 4(8/8)$

$= 12.75 > 10"$

↓

In Many Layers

2)]



Effective depth (d) = 20 − 1.5 − 3/8 − 8/8 − 1/2 (8/8)

d = 16.62

Effective Cover (d') = 1.5 + 3/8 + 1/2 (6/8)

= 2.25"

Step # 9

Moment of design is given by:-

$$M_d = \phi \times [A_{st}' \times f_y \times (d - d') + (A_{st} - A_{st}') \times f_y \times (d - a/2)]$$

$$a = \frac{(A_{st} - A_{st}') \times f_y}{0.85 \times f_c \times b}$$

$$= \frac{(5 \times 0.0785 - 1 \times 0.44) \times 60}{0.85 \times 4 \times 10} = 6.15''$$

$$M_d = 0.90 \times \{(1 \times 0.44) \times 60 \times (16.62 - 2.25) + (5 \times 0.785 - 1 \times 0.44) \times 60 \times (16.62 - 6.15/2)$$

$M_d = 2890.46$

As $M_d = 2890.46 > 2653.56$

So the Design is ok.

Q2, Part ⓐ **Briefly describe Bond Stress and Development length.**

Ans: **Bond stress** is primarily the result of the shear interlock between the reinforcing element and the enveloping concrete caused by the various factors previously enumerated. It can be described as a local shearing stress per unit area of the bar surface. This direct stress is transferred from the concrete to the bar interface so as to change the tensile stress in the reinforcing bar along its length.

Development length is the minimum embedment length of a bar in a concrete necessary to develop the yield stress in the bar, plus some additional distance to insure toughness.

→ if the distance from a point where the bar stress is equal to yield stress f_x to the end of the bar (zero stress) is less than the development ~~leng~~ length, then the bar will pull out of the concrete.

Q2 Part

ⓑ In which conditions doubly reinforced beam can be used?

Ans) Doubly reinforced beams can be used in place of singly reinforced beams when you have to reduce the depth of the beam but at the same time process will be more costly. Singly reinforced beam doesn't have compression steel but on the other hand doubly reinforced beam has. OR

Doubly reinforced concrete beams are used when aesthetic or functional requirements dictate that the beam needs to be smaller than that which can be accomodated using a single reinforced concrete beam.

Q2 Part

ⓒ Differentiate between T-beam analysis and rectangular beam analysis?

Ans: The main difference between a T. beam and a rectangular beam is of:

1) Geometry
2) Flexural capacity
3) Design procedure.

1) **In terms of design**, one is rectangular and the other is T-shaped. But one important point here is that T-beam offers more moment of inertia.

2) **The flexural capacity** of T-beam varies based on the sign of moment (positive or negative). The resistance of T beam is higher for positive moment because the flange section would be in compression. But for negative moment it yields the same strength as an equivalent beam without the flange. While the rectangular section only depends on the location of reinforcement to yield the flexural capacity.

3) **The design procedure** of T beam depends on the location of moment as the case of flexural strength. For positive moment we have three cases to be checked to proceed with design, one of of the neutral axis is within the flange, two; neutral axis outside of the flange or in the web and three; doubly reinforced T-beam. So before proceeding with the case, you need to make sure which case is your beam.

Q2
Part

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

Ans:- Strength reduction factor (R, factor) is defined as the ratio of elastic strength to yield strength. The importance of estimating R factor originates in the need for directly deriving inelastic spectra. However the flexural strength of a material is defined as the maximum bending stress that can be applied to that material before it yields.

In the design of flexural strength, the strength reduction factor φ decreases from tension-controlled sections to compression-controlled sections to increase safety with decreasing ductility.

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

Ans: There are three methods of structural design i.e

1) Working stress method (WSM)
2) Limit state method (LSM)
3) Ultimate load method of structural design (ULM)

These design methods are used for reinforced concrete as well as steel structure design.

1) Working stress Method:-

This was the traditional method of design not only for reinforced concrete but also for structural steel and timber design.

This method basically assumes that the structural material behaves in a linear elastic manner and that adequate safety can be ensured by suitably restricting the stresses in the material induced by the expected "working loads" on the structure.

This design usually results in relatively large sections of structural members, thereby resulting in better serviceability performance under the usual working loads.

2) Ultimate Load Method (ULM).

This method is sometimes referred to as the load factor method. In this method, the stress condition at the site of impending collapse of the structure is analyzed and the nonlinear stress-strain curves of concrete and steel are made use of

This method generally results in more slender sections, and often economical designs of beams and columns, particularly when high strength reinforcing steel and concrete are used.

3) Limit state Method (LSM)

The LSM philosophy uses a multiple safety factor format which attempts to provide adequate safety at ultimate loads as well as adequate serviceability at service loads, by considering all possible "Limit state".

Limit state: is a state of impending failure beyond which a structure ceases to perform its intended function satisfactorily, in terms of either safety or serviceability i.e it either collapses or becomes unserviceable. There are two types of limit states:-

1) Ultimate limit state collapse. deals with strength overturning, fracture etc.
2) Serviceability limit states: deals with discomfort, malfunction vibration, leakage etc.

Q3 A Concrete floor system consist of Parallel T beam spaced 10ft on centers & spanning 32ft between support. The 6inch Thick Slab is cast monolithically with beam web having width bw = 14inch and total depth measured from the top of the slab of h = 28inch less than the total depth ....?

Given Data:-

Thickness of Slab (hf) = 6"

L. length = 32'

L/C distance = 10'

Beam web width (bw) = 14"

Total depth (h) = 28"

Effective depth = 28" - 3" = 25"

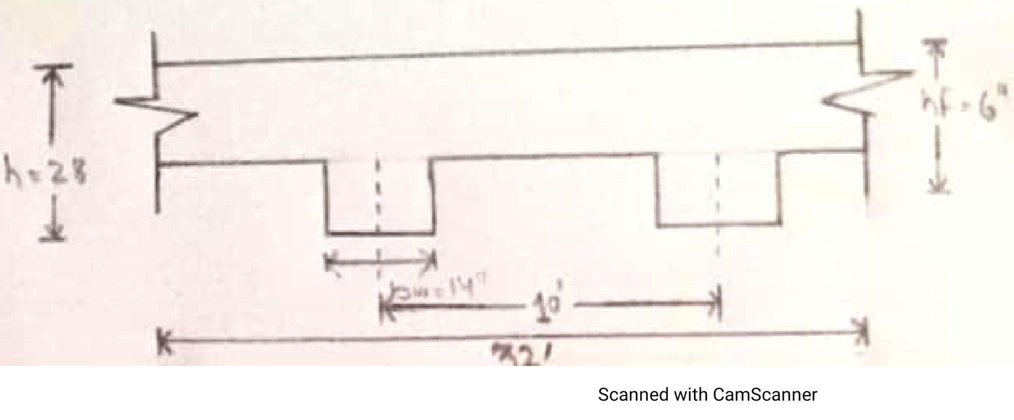
Dead load = 50 lb/ft²

Live load = 225 lb/ft²

f_y = 60000 psi = 60 ksi

f_c = 4000 psi = 4 ksi

Solution:-



Step#1

Ultimate Factored Moment

$$Mu = \frac{wu \times l^2}{8}$$

wu = Total Factored load.

Find Self weight per Feet:-

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

$$= 14/12 \times 28/12 \times 150$$

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

Find total Factored load

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

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

$$wu = 909.96\ lb/ft$$

$$wu = \mathbf{0.909\ kips/ft}$$

Now take Moment:-

$$Mu = \frac{wu \times l^2}{8}$$

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

$$Mu = \mathbf{1396.22\ kips\ inch}$$

Step# 2

Now calculate effective width "be".

1) $16 \times hf + bw = 16 \times 6 + 4 = 110''$
2) c/c distance $= 10 \times 12 = 120''$
3) Span/4 $= 32/4 \times 12 = 96''$

So, $\mathbf{be = 96''}$

Step# 3 To check Either Rectangular or I - beam.

Trial # 1

Let $a = h_f = 6$

$$A_{st} = \frac{M_u}{\phi \times f_y \times (d - a/2)} = \frac{1396.23}{0.90 \times 60 \times (25 - 6/2)}$$

$$A_{st} = 1.175 \text{ in}^2$$

Trial # 2

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

$$a = \frac{1.175 \times 60}{0.85 \times 4 \times 96}$$

$$a = 0.21'' < 6''$$

⇒ So rectangular beam Design

$$A_s = \frac{1396.23}{0.90 \times 60 \times (25 - 0.21/2)}$$

$$A_{st} = 1.03 \text{ in}^2$$

Trial # 3

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

$$a = \frac{1.03 \times 60}{0.85 \times 4 \times 96} = 0.18'$$

$$A_{st} = \frac{1396.23}{0.90 \times 60 / 25 - \frac{0.18}{2}}$$

$$A_{st} = 1.03 \text{ in}^2$$

Step#4

Check ρ_{max} and ρ_{min}:-

$$\rho_{max} = 0.85 \times B \times \frac{f_c'}{f_y} \times \left(\frac{\varepsilon_u}{\varepsilon_u + \varepsilon_t}\right)$$

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

$$\Rightarrow \rho_{max} = 0.018$$

$$= \rho_{min} = 200/f_y = 200/60000 = 0.003$$

$$\Rightarrow \rho = \frac{A_{st}}{b \times d} = \frac{1.03}{14 \times 25}$$

$$\rho = 0.00294$$

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

$$0.003 > 0.00294 < 0.018$$

As we know that
ρ is less than ρ_{min}

So $\rho = \frac{A_{st}}{b \times d} \Rightarrow A_{st} = \rho \times b \times d$

$$A_{st} = 0.003 \times 14 \times 25 = 1.05 in^2$$

Step#5

Selection and no of Bars

let try #8 main bar having area of one #10 bar

$= 1.27 in^2$

No of bars $= \frac{A_{st}}{A_b} = \frac{1.05}{0.785}$

$= 1.3 \approx 2$

So take 2 #8 main bars

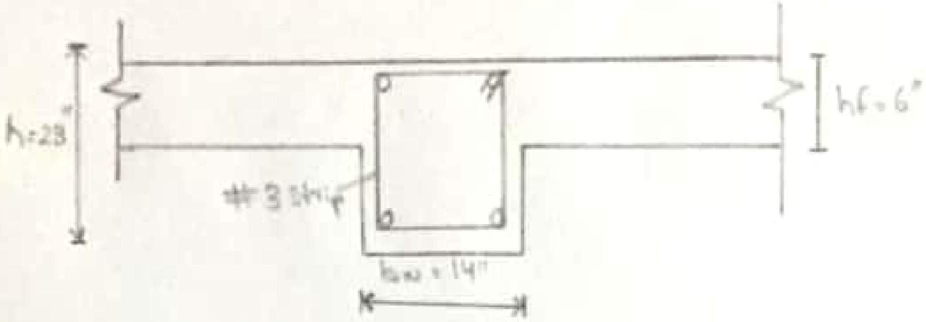
Step#6

Minimum width check out

$b_{min} = 2\times1.5 + 2\times(3/8) + 2(8/8) + 1(8/8)$

$b_{min} = 6.75'' < 14''$

So good in one layer



Step# 7

Now we calculate the design Moment as;

As we know that.

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

But first find "Ast" & "a"

Ast = Area of one bar × No of bars

$A_{st} = 0.785\times 2 = 1.57\ in^2$

$a = \dfrac{A_{st}\times f_y}{0.85\times f_c\times b_e} = \dfrac{1.57\times60}{0.85\times4\times96}$

$a = 0.2'$

$M_d = 0.90\times60\times1.57\times(25 - 0.2/2)$

$M_d = 2111.02$ kips-inc

$M_d = 2111.02\ k'' > M_u = 1396.23\ k''$

"The design is ok"