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Subject: PRCD

Semester: 6th

Section: "B"

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Question 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 18ft. Simple span is limited to 10 inches width and 20 inches total depth for architectural reasons. If fy = 60,000 psi and f'c = 4000 psi. what steel area must be provided? Draw sketch of your final design.

Step: 01 Beam Self weight:

$W_B = b * d * \gamma_c$

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

$= 208.33 \ lb/ft$

$d' = 2.5''$

$d = h - 3$

$d = 20 - 3$

$d = 17''$

Step: 02 Factored Load = Wu:

$W_u = (1.2 * D.L) + (1.6 * L.L)$

D.L ⇒ Dead Load

L.L ⇒ Live Load

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

$W_u = 5461.996 \ lb/ft \Rightarrow W_u = 5.46 \ Kip/ft$

Step: 03 Ultimate Factored Moment = MU =

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

$$Mu = \frac{5.46}{8} * 18^2 * 12$$

$$Mu = 2653.56 \text{ Kip-inch}$$

Step: 04 Check the capacity of reinforcement as Singly reinforced beam:

$$\rho max = 0.85 * \beta * \frac{f'c}{fy} * \left(\frac{\varepsilon u}{\varepsilon u + \varepsilon y}\right)$$

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

$$\rho max = 0.0180$$

Step: 05 Area of Steel = Ast:

$$\rho max = \frac{Ast}{b * d}$$

$$Ast = \rho max * b * d$$

$$Ast = 0.0180 * 10 * 17$$

$$Ast = 3.06 \, in^2$$

Step:06

$$MU_2 = \emptyset * Ast * fy * (d - a/2)$$

$\Rightarrow a = \dfrac{Ast * fy}{0.85 * f'c * b}$

$\Rightarrow a = \dfrac{3.06 * 60}{0.85 * 4 * 10}$

$\Rightarrow a = 5.4''$

$MU_2 = 0.90 * 3.06 * 60 * \left(17 - \dfrac{5.4}{2}\right)$

$MU_2 = 2362.93 K''$

$(MU_2 = 2362.93 \text{ Kip}'') < (MU = 2653.56 \text{ Kip}'')$

Step:07

$$MU_1 = MU - MU_2$$

$MU_1 = 2653.56 - 2362.93$

$MU_1 = 290.63 K''$

Step:08

$$MU_1 = \emptyset * A's * fy * (d - d')$$

$$A's = \frac{MU_1}{\emptyset * fy * (d - d')}$$

$A's = \dfrac{290.63}{0.90 * 60 * (17 - 2.5)}$

$A's = 0.37 in^2$

Step:09 Total Steel area

$$AS = Ast + A's$$

$As = 3.06 + 0.37$

$$As = 3.43\ in^2$$

Step:10 Selection of Bars:

⇒ For Tensile Steel:

Lets trying #8 bar for tensile Steel

* Area of #8 bar $= \frac{\pi}{4} * (8/8)^2$

$$= 0.785\ in^2$$

* Number of bars $= \frac{AS}{Ab} = \frac{3.43}{0.785} = 4.37 \approx 5$ bars

5 #8 bars

⇒ For compression Steel:

Lets trying #6 Bar for compression steel:

* Area of #6 bar $= \frac{\pi}{4} * (6/8)^2$

$$= 0.44\ in^2$$

* Number of bars $= \frac{A's}{Ab} = \frac{0.37}{0.44} = 0.84 \approx 1$ bar

1 #6 bar

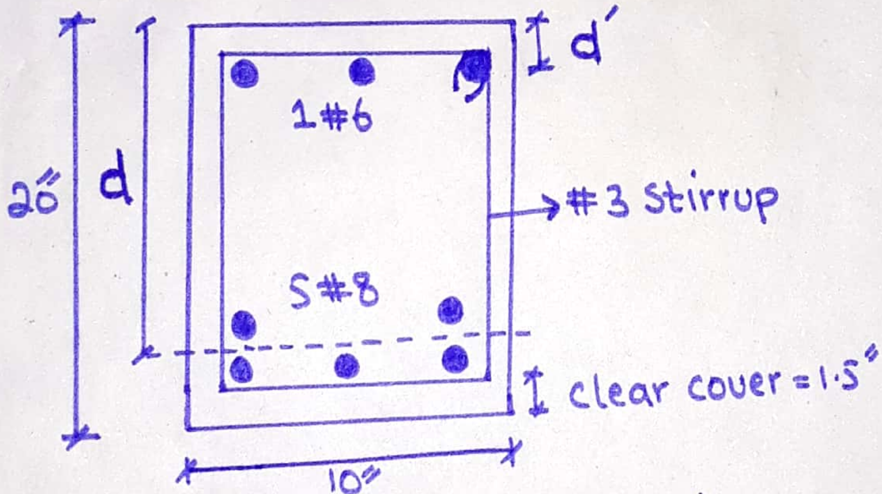
Step: 11 Check on mini-width of beam:

bmini = (2 * clear cover) + (2 * stirrup dia) + (no. of main bars * diameter of main bar) + (no. of spaces b/w main bars * dia of main bar).

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

$$b_{mini} = 12.75'' > 10''$$

⇒ not good in one layer, so main bars should be provided in two layers.



$d = 20 - (1.5 + 3/8 + 8/8 + (1/2 * 8/8))$

$$d = 16.625''$$

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

$$d' = 2.25''$$

Step:12 Design Moment = MD:

$$Md = \phi \left[A's * fy * (d-d') + (As-A's) * fy * (d - a/2) \right]$$

where $a = \dfrac{(As-A's) * fy}{0.85 * f'c * b}$

$$a = \frac{[(5*0.785)-(1*0.44)]*60}{0.85*4*10}$$

$$a = 6.15''$$

$$Md = 0.9\left[(1*0.44)*60*(16.625-2.25)+(3.485)*60*\left(16.625-\frac{6.15}{2}\right)\right]$$

$$Md = (0.9)(3212.805)$$

$$Md = 2891.52k' > Mu = 2653.56k'$$

⇒ Design is O.K!

Question no: 02

Part(a): Briefly describe Bond Stress and Development Length.

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: The necessary length between the Point of maximum stress in a bar and the end of the bar, is called Development length.

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

Ans: Doubly reinforced beam can be used in the following conditions:

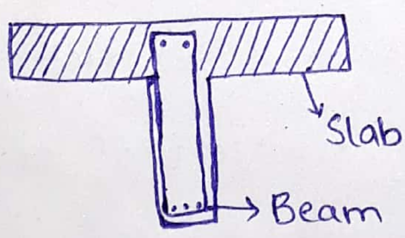
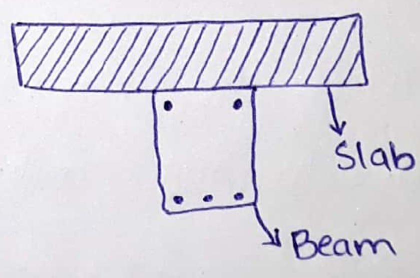
(i) when the cross section of beam is restricted due to any constraints like architectural or space consideration etc.

(ii) when the loads are eccentric.

(iii) when beam is subjected to accidental lateral loads.

(iv) In case of continuous beams or slabs, the sections at supports are generally designed as doubly reinforced sections.

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

T-Beam	Rectangular Beam
(i) Beam with T-Shape cross section is built when concrete beams are poured monolithically with slabs.	(i) Beam with rectangular shape cross section is built when concrete beams are poured polylithically with slabs.
(ii) There is no joint between slab and beam in T-Beams.	(ii) There is a proper joint between slab and beam in Rectangular shape Beams.
(iii) look like: 	(iii) look like: 
(iv) Slab and beam are constructed at the same time and it have different method of analysis.	(iv) Firstly Beams are constructed and then slabs over it are constructed and it have its own way of analysis.

Part (D): Write a short note on the effect of strength reduction factor on flexural strength.

Ans: Strength reduction factor is partially based upon how sudden a failure of the element will be. Beams have a better reduction factor because they tend to have more ductile failure.

* The deflection/cracking of concrete structures depend on flexure strength of concrete. Many factors have effect of strength reduction factor on flexural strength, particularly the level of stress, size, age, and confinement to flexure member etc.

Part (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 member design. which are the following:

(i) working stress Method

(ii) Ultimate load Method

(iii) limit State Method

(i) Working Stress Method: 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.

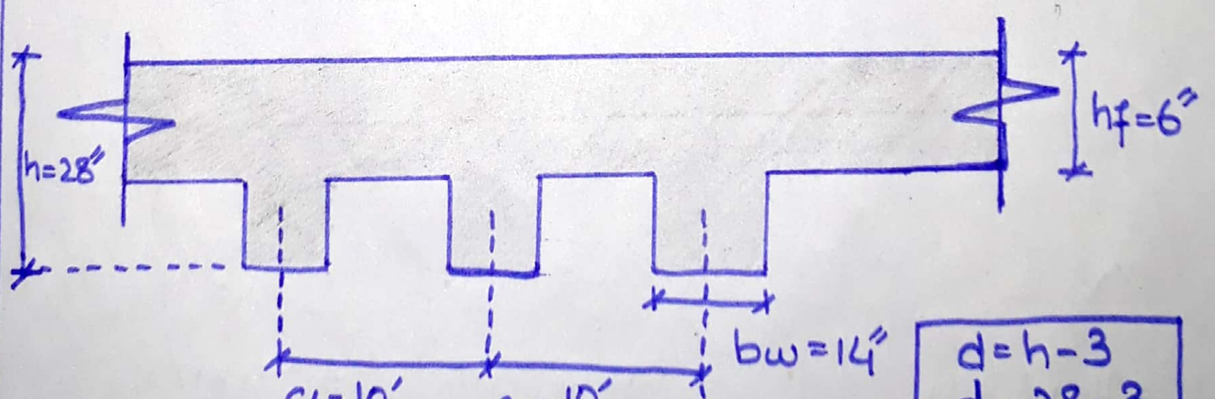
(ii) Ultimate Load Method: In this method, the stress condition at the site of impending collapse of the Structure is analyzed and the non-linear stress-strain curves of concrete and steel are made use of.

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

(iii) Limit State Method: The Philosophy of the limit State method of design represents a definite advancement over the traditional design philosophies.

⇒ Best Method: The more advanced and best method used nowadays is Limit State method because the L.S.M 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'.

Question no: 03 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 top of the slab, of $h = 28''$. The effective depth will be taken 3" Less then the total depth. In addition to its own weight, each beam must carry a superimposed D.L of 50PSF and Service Live Load of 225PSF. Material strength are $f_y = 60{,}000$ Psi, $f'_c = 4000$ Psi. Determine the required tensile Steel area and Select the reinforcement needed for a typical member. Draw sketch of your final design.



$d = h - 3$

$d = 28 - 3$

$d = 25''$

Step: 01 Beam Self weight per ft:

$$W_B = B * t * \gamma_c$$

γ_c = Unit weight of concrete

$$W_B = \frac{14 * 28}{12 * 12} * 150$$

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

Step: 02 Total Factored Load (Wu):

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

$= 909.99$ lb/ft

$$\boxed{= 0.909 \text{ kip/ft}}$$

Step: 03 Ultimate Factored Moment (MU):

$$\boxed{MU = \frac{W_u * L^2}{8}}$$

$$MU = \frac{0.909 * (32)^2}{8} * 12$$

$$\boxed{MU = 1396.224 \text{ kip}''}$$

Step: 04 Calculate Effective width "be":

(a): 16*hf + bw	(b): c/c distance	(c): Span/4
= 16*6+4	= 10*12	= $\frac{32*12}{4}$
= 110"	= 120"	= 96"

Step: 05 Selecting type of analysis:

Checking whether Rectangular or T-Beam analysis:

Trial 01):- let $a = h_f = 6''$

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

$$A_{st} = \frac{1396.224}{0.90 * 60 * (25 - 6/2)}$$

$$\boxed{A_{st} = 1.1752 \, in^2}$$

Trial 02):-

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

$$a = \frac{1.1752 * 60}{0.85 * 4 * 96}$$

$$\boxed{a = 0.2''} < 6''$$

⇒ hence rectangular beam design

$$A_{st} = \frac{1396.224}{0.90 * 60 * (25 - \frac{0.2}{2})}$$

$$\boxed{A_{st} = 1.04 \, in^2}$$

Trial 03):-

$$a = \frac{1.03 * 60}{0.85 * 4 * 96}$$

$$\boxed{a = 0.19''}$$

$$A_{st} = \frac{1396.224}{0.90 * 60 * (25 - \frac{0.19}{2})}$$

$$\boxed{A_{st} = 1.04 \, in^2}$$

Step 06):- checking up ρ_{max} and ρ_{mini}:

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

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

$$\boxed{\rho_{max} = 0.0180}$$

⇒ $$\rho_{mini} = \frac{200}{fy}$$

$$\rho_{mini} = \frac{200}{60,000}$$

$$\boxed{\rho_{mini} = 0.003}$$

⇒ $$\rho_{provided} = \frac{Ast}{b_w * d}$$

$$\rho_{provided} = \frac{1.04}{14 * 25}$$

$$\boxed{\rho_{provided} = 0.0029}$$

⇒ $$\boxed{\rho_{mini} > \rho_{provided} < \rho_{max}}$$

⇒ hence $\rho_{min} = \frac{Ast}{b * d}$

$$Ast = (\rho_{min}) * (b) * (d)$$

$$Ast = 0.003 * (14) * (25)$$

$$\boxed{Ast = 1.05 in^2}$$

Step:07 Selection & no. of Bars:

⇒ let us use #6 bar main bar

* area of one #6 bar = $0.44 in^2$

* no. of bars = $\frac{Ast}{Ab}$

$= \frac{1.05}{0.44}$

no of bars = 2.38 ≅ 3 bars

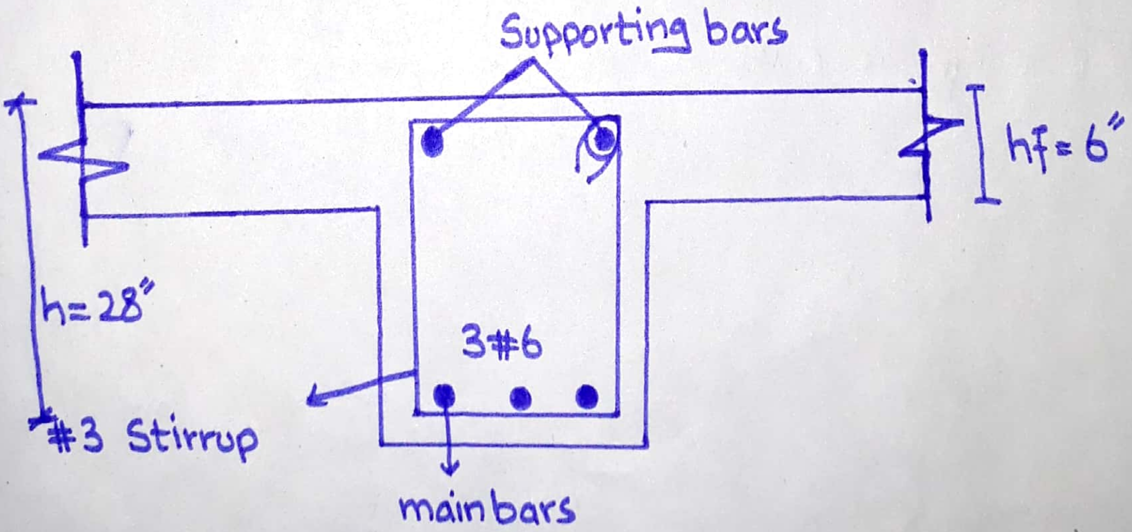
hence 3 #6 bars

Step: 08 check mini-width:

$b_{min} = (2*1.5)+(2*3/8)+(3*6/8)+(2*6/8)$

$b_{min} = 7.5''$ < $b_w = 14''$

⇒ hence main bars are good in one layer



Step: 09 Design Moment (M_D):

$$M_D = \varnothing * f_y * A_{st} * (d - a/2)$$

* firstly finding "Ast" and "a"

Ast = Area of one bar * no. of bars

Ast = 0.44 * 3

$A_{st} = 1.32 in^2$

$$a = \frac{A_{st} * f_y}{0.85 * f'c * b_e}$$

$$a = \frac{(1.32) * 60}{(0.85) * (4) * (96)}$$

$a = 0.24"$

$$M_d = 0.90 * 60 * 1.32 * \left(25 - \frac{0.24}{2}\right)$$

$M_d = 1773.45 \text{ kip}'$ > $M_u = 1396.224 \text{ kip}'$

Design is O.K!