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Section	A
Subject	PRCD I
Program	BSC Civil Engineering
Assignment	Plain & reinforced concrete design I
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Question 1

Stirup:

Stissups are closed-loop bars tied at regular intervals in beam reinforcement to hold the bars in position.

Types of stissups.

1- **single legged stissup.**

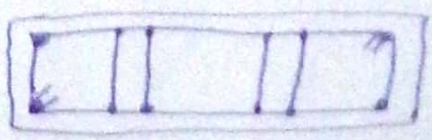
The single-leg stissups have rarely been used because they are mostly used when binding only two roads.

2- **Two legged stissup.** It is not commonly used stissup. Minimum 4 bars are required for providing this stisup.

3) **Four legged stissup.**

The stirip are used in case of web reinforcement.

4) **six leg stissip**



provided six legs for the better strength.

ACI code for shear design of a beam.

According to aci code ~~xx~~ 318, following are the formulas used for the shear design of a beam.

1- Critical section. occurs at 45° and is at distance (d) from the face of support which is equal to effective depth.

2- shear strength capacity

$\cancel{Vc} = \cancel{2x}$ $Vc = 2 \times \sqrt{f_c'} \times bw \times bd$

3- Minimum web reinforcement.

$$Av_{min} = \frac{0.75 \times \sqrt{f_c} \times bw \times S}{fy} \Rightarrow \frac{50 \times b \times S}{fy}$$

Higher value select

By interchanging the above formulas we can obtain

$$S_{max} = \frac{Av \times fy}{0.75 \times \sqrt{f_c} \times bw} \text{ or } \frac{Av \times fy}{50 \times bw}$$

lesser value selected

4- No-web reinforcement is required if:

$$V_u < \frac{1}{2} \phi V_c$$

so
$$S = \frac{\phi \times A_V \times f_y \times d}{V_u - \phi V_c}$$

5- if $V_s \le 4 \times \sqrt{f'c} \times b_w \times bd$. then max spacing for stirup will be the smallest of the following.

1 = 24''

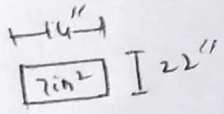
2 = d/2

3 - $S_{max} = \dfrac{A_V \times f_y}{0.75 \times \sqrt{f'c} \times b_w}$

4 = $S_{max} = \dfrac{A_V \times f_y}{50 \times b_w}$.

Question No 2

given data:



Breadth of web beam = $(b_w) = 14''$

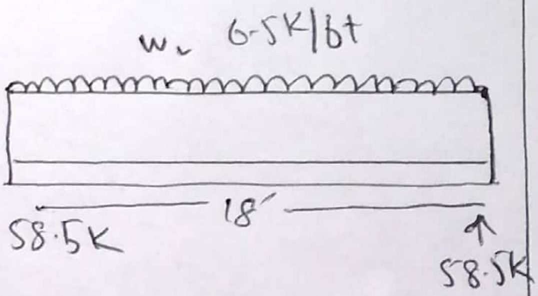
Effective depth = 22''

Given Load = 6.5 K/ft

Steel area = 7in²

$f'c = 4ksi$

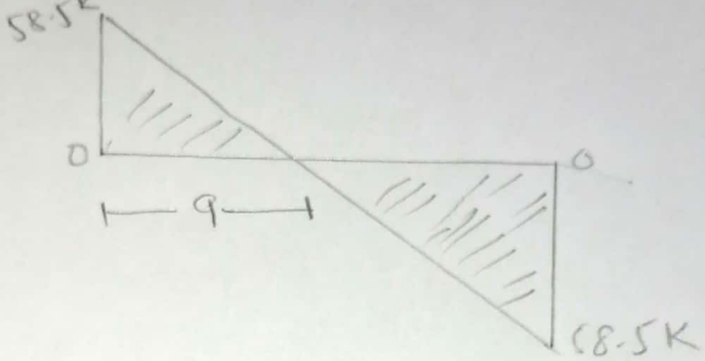
$f_y = 60 ksi$



Step # 1   Reaction on supports

Total load $= \frac{6.5 \times 18}{2} = 58.5$ kips

Step # 2   (Shear force Diagram)



Step#3

Find the value of critical shear and its location.

we know that critical shear is located at 'd' distance from face of support (d) = 22" = 1.83'

Now we will find the values of critical shear at distance 'd' by use of similar triangles.

from similar triangles

$$\frac{58.5}{9} = \frac{V_u}{8.17}$$

$$V_u = \frac{58.5 \times 7.17}{9}$$

$$\boxed{V_u = 46.61 \text{ kips}}$$

Step # 4

By formula

$$\phi V_c = \phi \times 2 \times \sqrt{f'_c} \times b_w \times d$$

$$= 0.75 \times 2 \times \sqrt{4000} \times 14 \times 22 = 29219 \text{ lbs}$$

$$= 29.21 \text{ kips.}$$

Location of ϕV_c by similar triangles

$$\frac{58.5}{9} = \frac{\phi V_c}{x_1} \Rightarrow \frac{58.5}{9} = \frac{29.21}{x_1}$$

$$\boxed{x_1 = 4.49'}$$

Similarly $\frac{1}{2}\phi V_c = \phi V_c/2 = 29.21/2 = 14.60$ kips.

$\Rightarrow$ location of $\frac{1}{2}\phi V_c$ will be

$$\frac{58.5}{9} = \frac{14.60}{x_2} \Rightarrow \boxed{x_2 = 2.24'}$$

Step # 5

By formula find the value of ϕV_s

$$V_v = \phi V_s + \phi V_c$$

$$\Rightarrow \phi V_s = V_v - \phi V_c$$

$$= 46.61 - 29.21$$

$$\boxed{\phi V_s = 17.4 \text{ kips}}$$

Step # 6

check on section adequacy.

By formula we know that

$= \phi \times 8 \times \sqrt{f'c} \times bw \times d$

$= 0.75 \times 8 \times \sqrt{4000} \times 14 \times 22 = 116877 \text{ lbs}$

$= 116.87 \text{ kips}$

so the section is adequate.

Step # 07

By formula

$= \phi \times 4 \times \sqrt{f'c} \times bw \times d$

$0.75 \times 4 \times \sqrt{4000} \times 14 \times 22 = 58438 \text{ lbs}$

$= 58.43 \text{ kips}$

AS $\phi \times 4 \times \sqrt{f'c} \times bw \times d > \phi V_s$

so maximum will be selected from the following 4 conditions.

1- $S_{max} = 24''$

2- $d/2 = 22/2 = 11''$

3- $S_{max} = \dfrac{Av \times fy}{0.75 \times \sqrt{f'c} \times bw}$

$3 = S_{max} = \dfrac{0.22 \times 60000}{.75 \times \sqrt{4000} \times 14} = 19.87''$

4- $S_{max} = \frac{A_v \times f_y}{50 \times b_w} = \frac{0.22 \times 60000}{50 \times 14} = 18.85'$

from above 4 condition, Least value of spacing for #3 2 legged stirrup will be selected as $s_{max} = 11''$

Step # 8

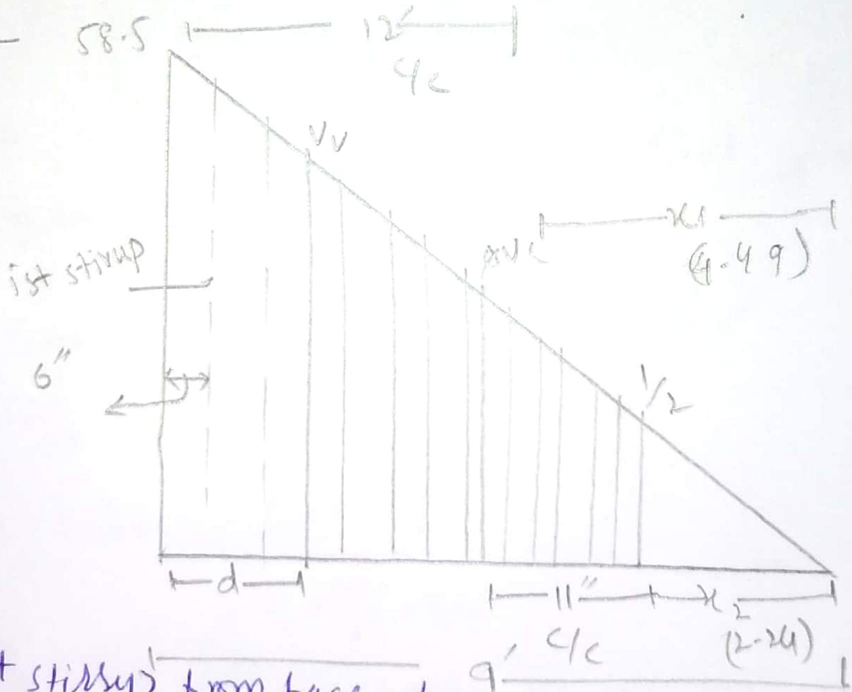
By formula

$$S = \frac{\phi \times A_v \times f_y \times d}{V_u - \phi V_c} = \frac{0.75 \times 0.22 \times 60 \times 22}{46.61 - 29.21}$$

$S = 12.5'' \approx 12''$

so $12''$ c/c

Step # 9



As first stirrups from face of support

$S/2 = 12/2 = 6''$

Question No 3

Solution, T-beams

In most of the reinforced concrete structors, concrete slabs are cast monolithically with the slab so, in this case the beam that act as an itermediate beam are called t- beams.

L beams

L- Shape structure that is in content with the slab and present at the corner of the floor is called L-beam.

Flexural strength of T-Beams.

- Following steps are below.

1- For finding the ultimate factored moment, we use the following formula

$$MV = \frac{WV \times L^2}{8}$$

2- Effective width (b_e) for T-beam is calculated as

1- $16(h_f) + b_w$

2- c/c distance

3- span/4

4- $\frac{CTS}{2} + b_w$

3) For finding area of steel,

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

∴ ϕ = strength reduction

where

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

4- For checking the range of reinforcement ratio.

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

$$\rho_{min} = \frac{200}{f_y}$$

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

5- formula for finding No. of bars required.

$$\text{No. of bars} = \frac{\text{Area of steel}}{\text{Area of single bar}}$$

Question No 4

Q= difference b/w case I and case II in the design of T-Beam?

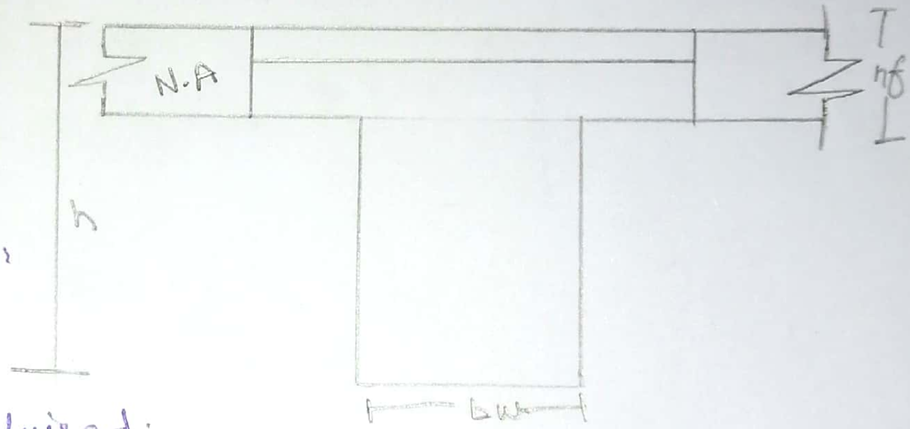
CASE I :

From the figure

$a < h_f$

So in this case,

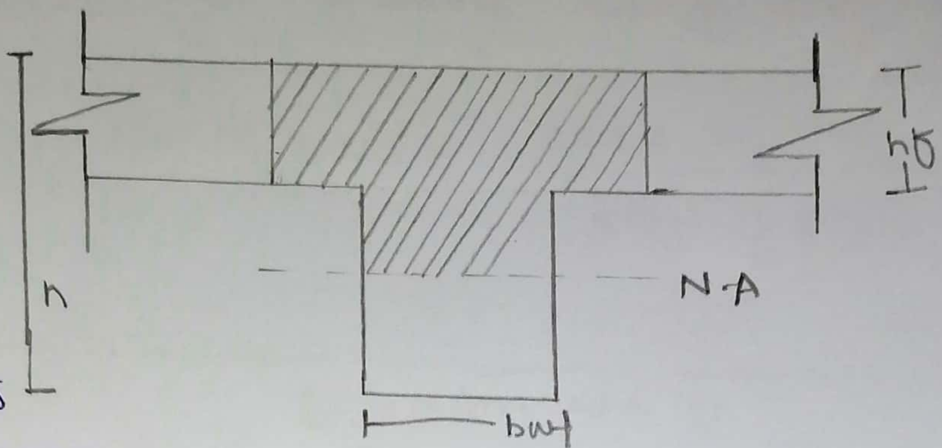
Rectangular beam analysis is required.



So, The design moment formula will be

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

Case II



from the figure $a > h_b$

So in, this special beam analysis i.e, T-beam analysis is required so the required design moment will be

$$M_d = \phi \times \left[A_S \times f_y \times \left(d - \frac{h_b}{2}\right) + (A_S - A_{st}) + f_y \times \left(d - \frac{a}{2}\right) \right]$$

Questioon No 5

Given data:

Height of flange $(h_b) = 3.5''$

c/c distance $= 9'$

Length /span of the beam $= 16'$

Web width $(b_w = 10''$

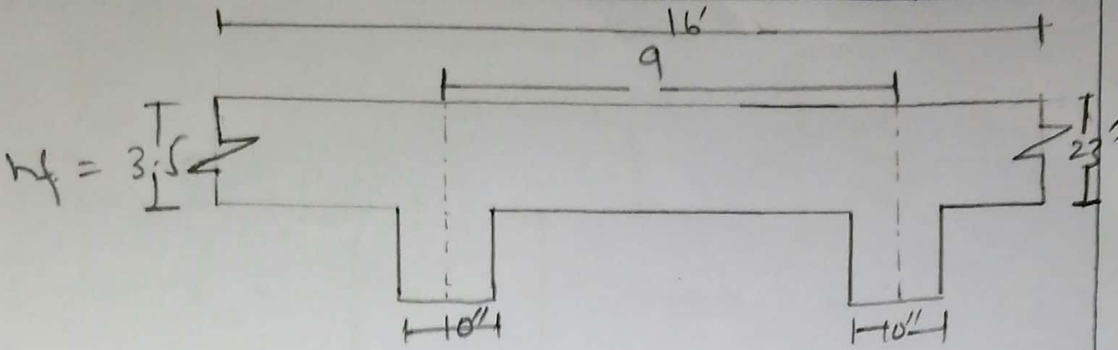
Effective depth $(d) = 18''$

height $(h) = 23''$

Total factored moment $(M_u) = 5800$ kip-inch

$f_c = 3$ksi , $f_y = 60$ ksi

Sol:



Step # 01

calculate the effective width (b_c) for T-beam.

1- $16(h_f) + b_w = 16(3.5)+10 = 66''$

2- c/c distance $= 9 \times 12 = 108''$

3- span/4 $= \frac{16}{4} = 12 = 48''$

selecting the least value $\Rightarrow 48''$

$\boxed{b_c = 48}$

step 2

$\Rightarrow$ Trial 1, let $a = h_f = 3.5''$

$$A_{st} = \frac{M_u}{\phi \times f_y \times (d - a/2)} = \frac{5800}{0.90 \times 60 \times (18 - 3.5/2)} = 6.61 in^2$$

$\Rightarrow$ Trial 2

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

$$a = \frac{6.61 \times 60}{0.85 \times 3 \times 48} = 3.2''$$

and $\boxed{a_{st} = 6.55 in^2} \Rightarrow 3.2'' < 3.5''$

⇒ Trial 3

$a = 3.21''$

and $A_{st} = \dfrac{5800}{0.90 \times 60 (18 - \frac{3.21}{2})} = \boxed{6.55 in^2}$

so are of steel is $6.55 in^2$

Step # 3

Now check ρ_{max} and ρ_{min}.

$= \rho_{max} = 0.85 \times \beta \times \dfrac{f'_c}{f_y} \left(\dfrac{\epsilon_u}{\epsilon_u + \epsilon_t} \right)$

$= 0.85 \times 0.85 \times \dfrac{3}{60} \left(\dfrac{0.003}{0.003 + 0.005} \right) = 0.013$

$\Rightarrow \rho_{min} = \dfrac{200}{f_y} = \dfrac{200}{60000} = 0.003$

$\Rightarrow \rho = \dfrac{A_{st}}{b \times d} = \dfrac{6.55}{10 \times 18} = 0.036$

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

$0.003 < 0.036 < 0.013$

As value of ρ_{max} is less than ρ, so we have to design it as doubly reinforced beam.

⇒ first we have to find the area of steel against ρ_{max}.

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

$$Ast = 0.013\ (10 \times 18)$$

$$\boxed{Ast = 2.34\ in^2}$$

Step # 04

Finding the value of Mu_2 :-

By formula

$$Mu_2 = \phi \times Ast \times fy \times (d - a/2)$$

first finding the value of 'a'

$$\Rightarrow a = \frac{Ast \times fy}{0.85 \times f'c \times b} = \frac{2.43 \times 60}{0.85 \times 3 \times 10}$$

$$a = 5.72''$$

$$\Rightarrow Mu_2 = 0.90 \times 2.43 \times 60 \times (18 - 5.72/2)$$

$$Mu_2 = \boxed{1986.67\ kip-inch}$$

As $Mu_2 < Mu$

$1986.7 < 5800$

so we have to design the beam in such away that it can resist more bending moment than the applied external moment.

Step # 05

Finding Difference in moments and area of steel.

$Mu_1 = Mu - Mu_2$
$= 5800 - 1986.67$

$Mu_1 = 3813.33$ kip-inch →

By formula

$$A'_{st} = \frac{Mu}{\phi \times fy \times (d-d')} = \frac{3813.33}{0.90 \times 60 \times (18-2.5)}$$

$$\boxed{A'_{st} = 4.56 \, in^2}$$

Step # 6

section of Bar.

In tension zone

let we use # 8 bar

dia $= 8/8 = 1''$, Area $= \frac{\pi}{4}(1)^2 = 0.785 \, in^2$

$$\text{No of bars} = \frac{\text{Area of steel}}{\text{Area of single bar}} = \frac{6.99}{0.785} = 8.9 \simeq 9$$

So 9 #8 bars

while in compression zone

let we use #7 bar

dia $= (7/8)''$, Area $\frac{\pi}{4}(7/8)^2 = 0.601 \, in^2$

Now By the help of formula

$$\text{No of bars} = \frac{\text{Area of steel}}{\text{Area of single bar}} = \frac{4.56}{0.601} = 7.5 \approx 8$$

So 8 # 7 bars

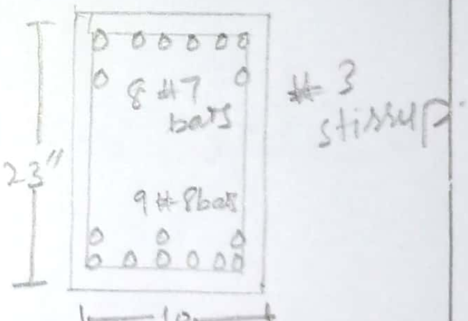
Step # 8

Minimum ~~depth~~ width for accomodation of bars.

$$b_{min} = (2 \times 1.5) + (2 \times 3/8) + 9(8/8) + 8(8/8)$$
$$= 20.75''$$

As $20.75'' > 10''$

So, the bars will be placed in multiple layers.



Effective depth (d).

$$= 23 - 1.5 + \frac{3}{8} + \frac{8}{8} + \frac{1}{2}(8/8) = 19.6''$$

Effective cover (d').

$$= 1.5 + 3/8 + 7/8 + 1/2(7/8) = 3.18''$$

Step # 9

binding the design moment.

$$Md = \phi \{ A_s' \times f_y \times (d - d') + (A_s - A_{st}) \times f_y \times (d - a/2)$$

$$\text{first } a = \frac{A_s - A_s' \times f_y}{0.85 \times f_c \times b} = \frac{(9 \times 0.785 - 8 \times 0.601) \times 60}{0.85 \times 3 \times 10} = 5.31''$$

$$\Rightarrow Md = 0.90 [(8 \times 0.601) \times 60 \times (19.6 - 3.18) + (9 \times 0.785 - 8 \times 0.601) \times 60 \times (19.6 - 5.31/2)]$$

$$\boxed{Md = 6328.38}$$

As 6328.38 ⇒ 5800 → so design is ok!

Question No 6

Solution:

Given.

Breadth (b) = 14''

Height (h) = 26''

concrete compression strength ($f'c$) = 4 ksi

Steel tensile strength (f_y) = 60 ksi

ultimate factored moment (M_u) = 6000 kip-inches

Effective depth of beam (d) = 22''

Assume Effective cover (d') = 2.5''

Step # 1 (Reinforcement ratio)

we know that

$$\rho_{max} = 0.85 \times \beta \times \frac{f'c}{fy} \times \left(\frac{\epsilon u}{\epsilon u + \epsilon y}\right)$$

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

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

Step # 02 (Area of steel)

As we know that

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

$$\Rightarrow Ast = 0.0180 \times (14 \times 22) = \boxed{5.54 \, in^2}$$

Step # 3 (Design moment)

we know that

$$M_{U2} = \phi \times Ast \times fy \times (d - a/2)$$

$$\Rightarrow a = \frac{Ast \times fy}{0.85 \times f'c \times b} = \frac{5.54 \times 60}{0.85 \times 4 \times 14} = \boxed{6.98''}$$

so $M_{U2} = 0.90 \times 5.54 \times 60 \left(22 - \frac{6.98}{2}\right)$

$= 5537.4$ kip-inch

As $5537.4 < 6000$

So we have to design a section as doubly reinforced.

Step # 04 (Difference in moments)

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

$$= 6000 - 5537.4$$

$$M_{u1} = 462.6 \text{ kip-inch}$$

Step 5 (Area of steel)

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

So area of steel in compression zone will be,

$$\Rightarrow A_{st} = \frac{M_{u1}}{\phi \times f_y \times (d-d')} = \frac{462.6}{0.90 \times 60 \times (22-2.5)}$$

$$\Rightarrow \boxed{A'_{st} = 0.44 \text{ in}^2}$$

Step # 6 (Total steel area)

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

$$= 5.54 + 0.44 = 5.98 \text{ in}^2$$

Step # 7 (selection of No of bars used)

1- Steel in tension zone

we use #7 bar

dia $= (7/8)'' = 0.875''$, Area $= \frac{\pi}{4}(0.875)^2$

$= 0.601 \text{ in}^2$

so No. of bars = $\frac{A_{st}}{\text{area of single bar}}$

$= \frac{5.98}{0.601} = 9.9 \approx 10$ bars

So 10 #7 bars.

2 Steel in compression zone

we use #5 bar

dia $= (5/8)'' = 0.625''$, Area $= \frac{\pi}{4}(0.625)^2$
$= 0.306 in^2$

so No of bars $= \frac{A_{st}'}{\text{area of single bar}} =$

$= \frac{0.44}{0.306} = 1.43 \approx 2$ bars

So 2 #5 bars

Step # 8 (Minimum width of beam)

$b_{min} = 2(1.5) + 2(3/8) + 10(7/8) + 9(7/8)$

$b_{min} = 20.37 > 14''$
so not good in one layer

Now effective depth.
$d = 26 - 1.5 - 3/8 - 7/8 - 1/2\,(7/8) = 22.82''$

Effective cover $(d') = 1.5 + 3/8 + 1/2\,(5/8)$
$= 2.18''$

Step # 09 (Design moment)

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

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

$$= \frac{10 \times 0.601 - 2 \times 0.306 \times 60}{0.85 \times 4 \times 14} = 6.80''$$

$$Md = 0.90[(2 \times 0.306) \times 60 \times (22.82 - 2.18) + (10 \times 0.601 - 2 \times 0.306) \times 60 \times (22.82 - 6.80/2)]$$

$Md = 7047.6$ kip-inches

As = 7047.6 7 6000

Design is ok!