Student No :_____

Design of Exterior Girder : Section 10-10:

M_u (+ve) = 2092.2 k-ft

M_u (-ve) = -3344.2 k-ft

For +ve Moment

H = 67"

$b_{eff} = \frac{1}{2}s_{cl} + \frac{1}{2}b_w + \text{sidewalk} = 3.75' + \frac{9''}{12} + 3.5 = 8' = 96''$

Assuming triple layer of reinforcement, $d = H - 2.5 \times 2 = 67'' - 5'' = 62''$

Let, $a_{initial} = t_s = 7.5''$

$A_{s,initial} = M_u / \phi f_y (d - \frac{a}{2}) = 2092.2 \times 12 / .9 \times 60 (62 - \frac{7.5}{2}) = 7.98 in^2$

$a_{revised} = A_s f_y / .85 f'_c b_{eff} = 7.98 \times 60 / .85 \times 5 \times 96 = 1.17 in < t_s$

∴ It is a rectangular beam.

Now, $A_s = \frac{M_u / \phi f_y (d - \frac{a}{2})}{= \frac{2092.2 \times 12}{.9 \times 60 (62 - \frac{a}{2})}}$

$= 7.82 in^2$

$a = A_s f_y / .85 f'_c b_{eff} = A_s \times 60 / .85 \times 5 \times 96 = 1.15 in$

$A_{s,min} = \frac{200}{60000} b_w d = \frac{200}{60000} 18 \times 62 = 3.72 in^2 < A_s$

Now, $c = \frac{a}{\beta_1} = \frac{1.15}{.8} = 1.44 in$

$\beta_1 = 0.85 - 0.05 (\frac{f'_c - 4000}{1000})$

$= 0.85 - .05 \times \frac{(5000 - 4000)}{1000}$

$= 0.8$

$c < \frac{3}{8} d \Rightarrow 1.44 < \frac{3}{8} 62 \Rightarrow 1.44 < 23.3$

∴ Tension controlled.

∴ 10 #9 bar as positive reinforcement. $A_{s,prov} = 10 \times 1 = 10 in^2$

Student No :

For -ve moment

H = 67"

Assume double layer of reinforcement, d = H - 4 = 67 - 4 = 63"

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

$= \frac{3344.2 \times 12}{.9 \times 60 (63 - \frac{a}{2})}$

$= 12.82 \text{ in}^2$

$a = A_s f_y / .85 f_c' b_w$

$= \frac{A_s 60}{.85 \times 5 \times 18}$

$= 10.1 \text{ in}$

$A_{s,min} = \frac{200}{f_y} b_w d = \frac{200}{60000} 18 \times 63 = 3.78 \text{ in}^2 < A_s$

Now, $c = \frac{a}{\beta_1} = 10.1/.8 = 12.6"$

$c < \frac{3}{8} d \Rightarrow 12.6 < 23.6$

∴ Tension controlled.

∴ 8 #9 and 4 #10 as negative bar. $A_{sprov} = 8 \times 1 + 4 \times 1.27$

$= 13.08 \text{ in}^2$

Design of Haunch Reinforcement:

#3 bar at 6" c/c along the length of girder.

Student No :_____

Design for Shear Reinforcement:

$V_u = 248.9K$

$d = 62''$

$V_u (248.9K) < .25\phi f_c' b_w d \quad (.25 \times .9 \times 5 \times 18 \times 62 = 1255.5K)$

$\therefore$ Concrete dimension is ok.

Now $\phi V_c = \phi .0316 \beta \sqrt{f_c'} b_w d = .9 \times .0316 \times 2 \times \sqrt{5} \times 18 \times 62 = 141.9K$

$V_u (248.9K) > \frac{1}{2} \phi V_c (70.9K)$ $\therefore$ Stirrup is required.

Let, #3 bar 4-legged stirrup. $\therefore A_v = 4 \times .11 = .44 \text{ in}^2$

$$S_{required} = \frac{\phi A_v f_y d}{V_u - \phi V_c} = \frac{.9 \times .44 \times 60 \times 62}{248.9 - 141.9} = 13.7'' \approx 13.5''$$

Check S_{max}:

$V_u (248.9K) < .125 \phi f_c' b_w d \quad (.125 \times .9 \times 18 \times 62 = 620.8K) \rightarrow .8d$

$$\therefore S_{max} = \min \begin{cases} \frac{A_v f_y}{.0316 \sqrt{f_c'} b_w} = \frac{.44 \times 60}{.0316 \times \sqrt{5} \times 18} = 20.5'' \\ .8d = 49.5'' \\ 24'' \end{cases}$$

$\therefore$ #3 - 4 legged @ 13.5" c/c stirrup.

Student No : _____

Design of Skin Reinforcement:

For +ve moment: $d_1 = d = 68''$ $A_s = 10\ in^2$

$0.012(d_1 - 30) \le A_{sk} \le A_s/4 \Rightarrow 0.012(62-30) \le A_{sk} \le \frac{10}{4} \Rightarrow 0.384 \le A_{sk} \le 2.5\ in^2$

Spacing $s_{max} = \begin{cases} d_1/6 = 62/6 = 10'' \\ 12'' \end{cases}$

Skin Rein should be provided to a height of $\frac{d_1}{2} = \frac{62}{2} = 31''$

Let, provide #7 bar @ 8" c/c

$A_{sk\,prov} = \frac{12 \times A_b}{s_{prov}} = \frac{12 \times 0.6}{8} = 0.9\ in^2$ per ft.

$\therefore 0.384 \le 0.9 \le 2.5\ in^2$ $\therefore$ OK

$\therefore$ #7 bar @ 8" c/c as positive skin Reinforcement.

For negative moment: $d_1 = d = 63''$ $A_s = 13.08\ in^2$

$0.012(d_1 - 30) \le A_{sk} \le \frac{A_s}{4} \Rightarrow 0.012(63-30) \le A_{sk} \le \frac{13.08}{4} \Rightarrow 0.4 \le A_{sk} \le 3.3\ in^2$

Spacing, $s_{max} = \begin{cases} d_1/6 = 63/6 = 10.5'' \\ 12'' \end{cases}$

Skin rein should be provided to a height of $\frac{d_1}{2} = \frac{63}{2} = 31.5''$

Let provide #7 @ 10" c/c

$A_{sk,\,prov} = \frac{12 \times A_b}{s_{prov}} = \frac{12 \times 0.6}{10} = 0.72\ in^2$ per ft

$\therefore 0.4 < 0.72 < 3.3$ $\therefore$ OK

$\therefore$ #7 @ 10" c/c as negative skin reinforcement.

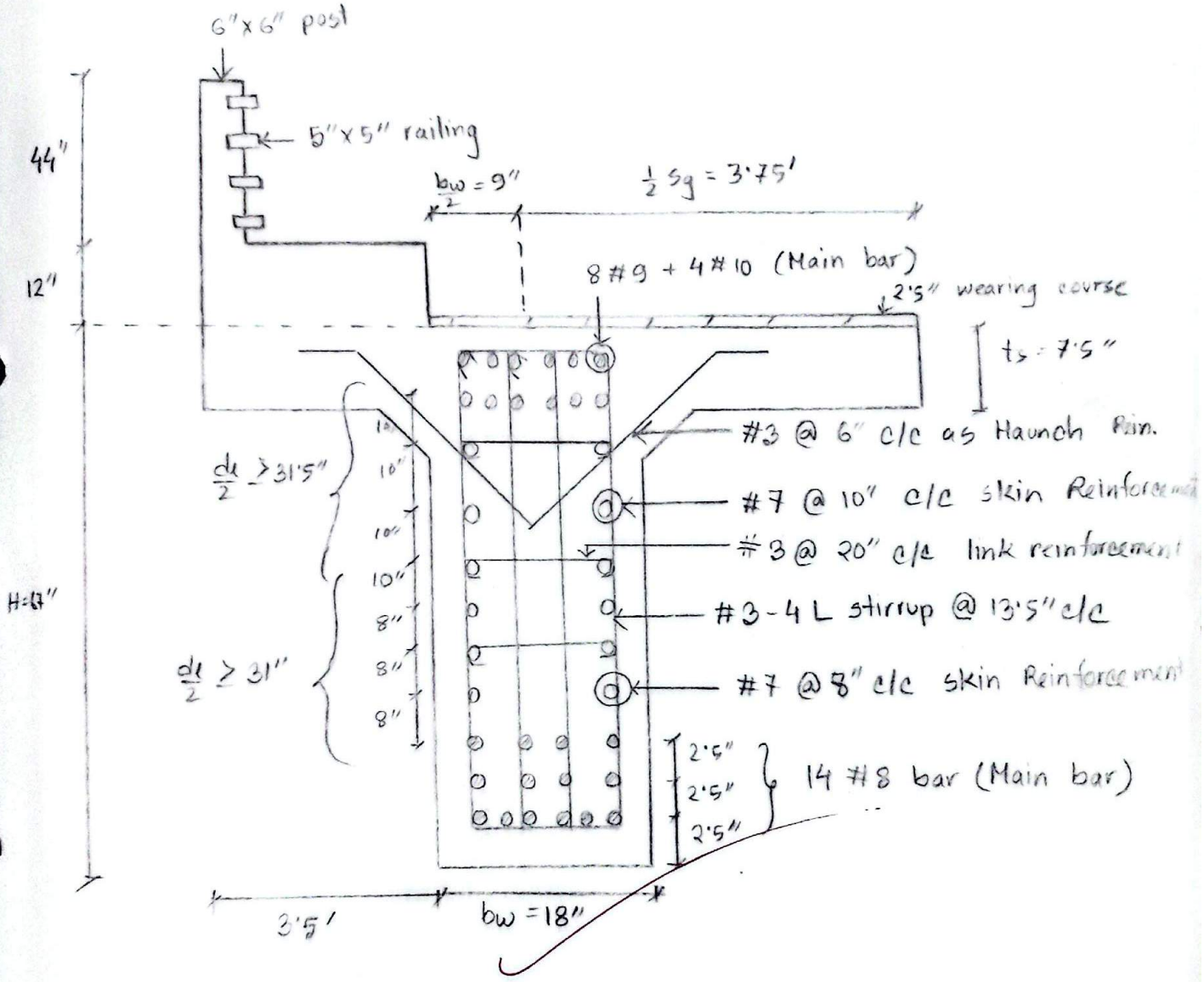


fig: Exterior Girder at section 10-10

Reinforcement Detailing