CVG3148 - ASSIGNMENT 5 - Solutions

Problem 1 (30 marks):

a) Original design:

$\rho = \mathbf{3.14}\% > \rho_b = \mathbf{2.27}\% \Longrightarrow$ the actual design is an over – reinforced beam

b) Revised design

Since $\rho = \mathbf{3.14}\% < \rho_{max} = 2.27\% + 1.25\% = \mathbf{3.52}\%$ the beam reinforcement is **OK.**

c) M_r without using CDH Tables:

$T = \phi_s f_y A_s$

$C_S = \phi_s f_y A_S^{'}$

$C_C = \alpha_1 \phi_c f_c^{'} ba$

Compression Reinforcement at the plastic stage ($f_s^{'} = f_y = 400$ MPa)

At The equilibrium: $C = T \Longrightarrow T = C_S + C_C = C_S + \alpha_1 \phi_c f_c^{'} ba$ (To check)

- $a = \mathbf{275\ mm}$

$T = 2380$ kN

$C_S = 952$ kN

$C_C = 1430$ kN

$\Longrightarrow T = C_S + C_C$

- $c = \mathbf{305 mm}$
- check if $A_S^{'}$ and A_s are in the plastic range

$A_s\ (\varepsilon_s \geq \varepsilon_y\ );\ \varepsilon_s = \mathbf{0.0029} \geq \varepsilon_y = 0.002$ OK

$A_S^{'}\ (\varepsilon_s^{'} \geq \varepsilon_y\ ); \varepsilon_s^{'} = \mathbf{0.0029} \geq \varepsilon_y = 0.002$ OK

$M_r = 1079\ \text{kN.m}\ > \ M_f = 850\ \text{kN.m}$ **OK**

d) M_r Using CDH Tables:

$\rho^{'} = \mathbf{1.25}\%$ →By linear Interpolation (Table 2.2): For $\rho^{'}\% = 1.25\%$ and $\frac{d^{'}}{d} = 0.1,\ k_r^{'} = 3.83\ \text{MPa}$

$\rho = \mathbf{1.88}\%$ →By linear Interpolation (Table 2.1):For $\rho = \mathbf{1.88}\%,\ k_r = 4.85\ \text{MPa}$

$M_r = 1081.06\ \text{kN.m}$

The result is close to what is found by analytical method.

Problem 2 before update (30 marks):

$d = 341.5mm$

$d^{'} = 54mm$

We should keep $M_r \geq M_f$ (Assume $M_r = M_f = 650\ \text{kN.m}$)

$k_r = \mathbf{9.29\ MPa}$

In Table 2.1 in CSA A23.3: No value for ρ% corresponds to this case ($k_r = 9.29$ MPa and $f'c = 40$ MPa) .

Provide maximum tension reinforcement given in table 2.1

$$k_{r,max}\left(f_c^{'} = 40\ \text{MPa}\ \right) = 8.2\ \text{MPa} \rightarrow \text{ correspond to } \rho_b = 3.33\%$$

$k_r^{'} = 9.29MPa - 8.2MPa = 1.09\ MPa$

We must use compression reinforcement too.

$\rho^{'} = \mathbf{0.38}\%$

$A_S' = \mathbf{778.62}\ mm^2$

Use 2-25M → $A'_S = 1000mm^2 > 778.62\ mm^2$.

Recalculate: $\rho' = \mathbf{0.00488}$
Recalculate : $k_r' = 0.00488(1 - 0.158) * 0.85 * 400 = \mathbf{1.4\boldsymbol{MPa}}$

$M_{r1} = \mathbf{573.78\ kN.m}$

M_{r2} = **97.96 kN.m**

$M_r = 573.78 + 97.96 = 671.74\ kN.m > M_f = 650\ kN.m$ **OK**

Required Tension Reinforcement:

$\rho = 3.33\% + 0.38\% = 3.71\ \%$

$A_S = 7601.79\ mm^2$

We can use 16 – 25M distributed in two layers (8-25M in each)

Check Bar spacing:

$s = \mathbf{45\boldsymbol{mm}}$

Bar spacing:

$$s = 45mm \geq \begin{cases} 35mm \\ 28mm \\ 30mm \end{cases}$$ **OK**

Check $\boldsymbol{A_S > A_{Smin}}$:

$A_S = 8000mm^2 > A_{Smin}$=815.87$mm^2$ **OK**

Maximum Reinforcement:

$\rho = \mathbf{3.9}\%$

$\rho' = \mathbf{0.488}\%$

$\rho_b = \mathbf{3.33}\%$

$\rho = \mathbf{3.9}\% > \rho_{max} = \mathbf{3.33}\% + \mathbf{0.488}\% = \mathbf{3.818}\%$ **NOT OK**

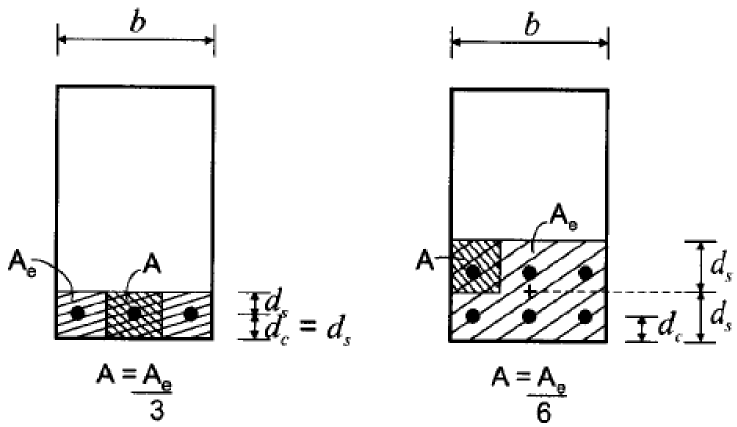
Increase A_S' and use 3-25M → $A_S = 1500mm^2 > 778.62\ mm^2$

$\rho' = \mathbf{0.732}\%$

$\rho_b = \mathbf{3.33}\%$

$\rho\ = \mathbf{3.9}\%\ >\ \rho_{\max} = \mathbf{3.33}\% + \mathbf{0.732}\% = \mathbf{4.062}\%$ **OK**

Crack controlling (Z factor):



For Interior exposure: $z = f_s\sqrt[3]{d_c A} < 30000 N/mm$

$f_s = 240 MPa$

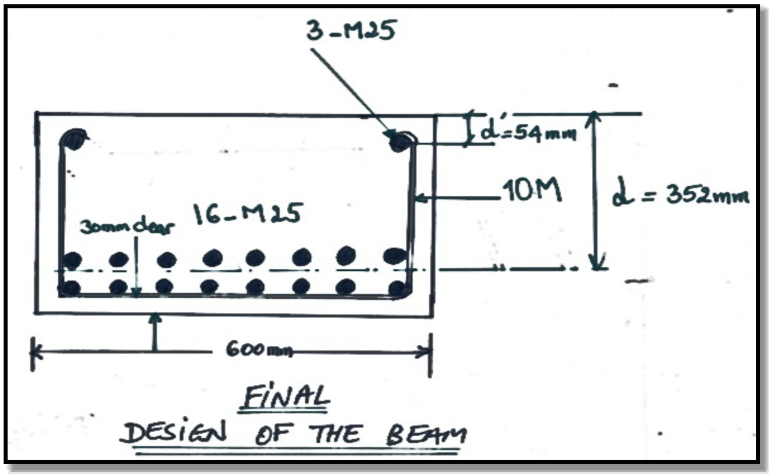
- $d_c = 54\ mm$
- $d_s = 89\ mm$

$N = number\ of\ bar$s

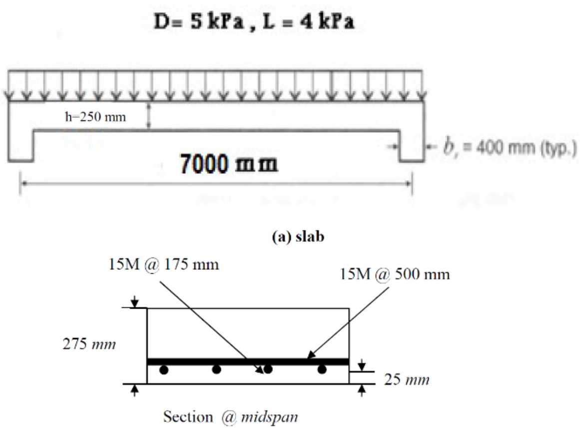
$A_e = \mathbf{106800 mm^2}$

$A = \mathbf{6675 mm^2}$

$z = \mathbf{17080 N/mm} < 30000 N/mm$ **OK.**



Problem 2 (30 marks):



(b) slab design details

$L_n = \mathbf{6600\ mm}$

$q_f = \mathbf{12.3\ kPa}$

$W_f = \mathbf{12.3\ kN/m}$ Per (m) width of slab

$M_f = \mathbf{67\ kN/m}$ Per (m) width of slab

$d = 275 - 25 = \mathbf{250\ mm}$

a)

As → 15M @ 175 mm

$As = \mathbf{1143\ mm^2/m}$

$a = \mathbf{21.35\ mm}$ $M_r = \mathbf{93\ kN.m} > \mathbf{M_f = 67 kN.m}$

→ Strength requirement is met.

Check s_{max} and As_{min} requirements of CSA standard.

$As_{min} = \mathbf{550\ mm^2/m}, \quad \mathbf{1143 > 550 \quad OK}$

$s_{max} \rightarrow min \begin{cases} 825 \\ 500 \ \rightarrow control \end{cases}$ **s = 175 < 500 OK**

b)

$As = \mathbf{400 mm^2/m},\ As_{min} = \mathbf{550\ mm^2/m},\ \mathbf{As < As_{min}\ \ Not\ OK!!}$

$s_{max} \rightarrow min \begin{cases} 1375 \\ 500 \ \rightarrow control \end{cases}$ **s = 500 ≤ 500 OK**

c)

h ≤ 350 $\rightarrow \beta = 0.214$

$d_v \rightarrow max \begin{cases} 0.9d = 225\ mm \ \rightarrow control \\ 0.72h = 198 \end{cases}$

$V_C = \mathbf{181.7\ kN}\ \ (Per\ m\ width)$

$V_R = V_C = 181.7$ kN

$V_f = \mathbf{41\ kN}\ \ (Per\ m\ width)$

Since VR > $\boldsymbol{V_f}$ **OK**