

- **Problem 1:**

a)

$$\alpha_1 = 0.80, \beta_1 = 0.88$$

$$\rho_{bal} = 3.0\%$$

$$K_r = 5.1 \text{ MPa}$$

$$W_f = 36.5 \text{ kN/m}$$

$$M_f = 164.25 \text{ kN}\cdot\text{m}$$

Three approaches To estimate h: **Choose h = 450 mm**

b) Design the beam such that $M_r \geq M_f$

clear cover= 30mm, assume cover to centroid of steel=60mm

$$d = 390\text{mm}$$

$$a = 96.5 \text{ mm}$$

Use $A_s > 1414 \text{ mm}^2$:

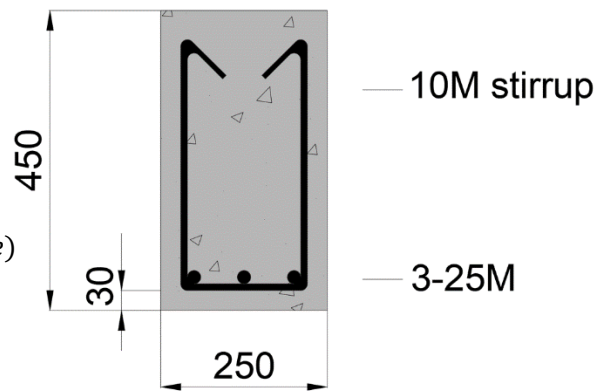
Use 3-25M bars, $A_s = 1500\text{mm}^2$

Following clauses have to be Checked:

- i. $A_s \leq A_{s_{max}} \quad 1.51\% < \rho_{bal}(3.2\%)$
- ii. $\rho \leq \rho_{bal} \quad 1.51\% < \rho_{bal}(3.2\%)$
- ii. $A_s \geq A_{s_{min}} \quad 1500 > 356$
- iii. $\left(\frac{c}{d}\right) < \left(\frac{c}{d}\right)_{max} \quad 0.29 < 0.64$
- iv. $M_r > M_f \quad M_r = 177.4 \text{ kN}\cdot\text{m} > M_f = 164.25 \text{ kN}\cdot\text{m}$

c) Veify other requirements in the CSA A23.3:

1. **Minimum cover** 30 mm
2. **Minimum bar spacing, s**
 $s = 47.5\text{mm} > s_{min} = 35\text{mm}$
3. **Crack Control (z-factor)**
 $z = 18515 \text{ N/mm} < 25000 \text{ N/mm (for normal exposure)}$
4. **Skin Reinforcement**
5. **Deflection limit**



Problem 2:

a) Design critical beam section in negative bending

$$W_f = 135 \text{ kN/m}$$

$$M_f = 583.2 \text{ kN}\cdot\text{m}$$

$$\alpha_1 = 0.79$$

$$\beta_1 = 0.87$$

Cover: 60mm

effective depth (d): 717.5 mm

$A_{s(\text{required})}$: $M_f = M_r = 583.2 \text{ kN}\cdot\text{m}$

$$K_r = 2.266 \quad \rho = 0.72\% , \rho_{bal} = 3.34\% \quad A_s = 2583 \text{ mm}^2$$

use 6-25M bars , ($A_s = 6 \times 500 = 3000 \text{ mm}^2$)

Checks:

1. $A_s \leq A_{s_{max}} , \rho \leq \rho_{bal}$

$$0.84\% < \rho_{bal}(3.34\%)$$

2. $A_s \geq A_{s_{min}}$

$$A_s \geq A_{s_{min}} , 3000 > 1265$$

3. $\left(\frac{c}{d}\right) < \left(\frac{c}{d}\right)_{max}$

$$0.16 < 0.64$$

4. $M_r > M_f$

$$M_r = 681.2 \text{ kN}\cdot\text{m} > M_f = 583.2 \text{ kN}\cdot\text{m}$$

5. **minimum bar spacing, s**

$$s = 42 \text{ mm} \geq s_{min} = 35 \text{ mm}$$

6. **Crack Control (z-factor)**

- $z = 22964 \frac{\text{N}}{\text{mm}} < 25000 \frac{\text{N}}{\text{mm}}$ (for normal exposure)

b) Design critical beam section in positive bending:

$$\alpha_1 = 0.79 , \beta_1 = 0.87 , c=60 \text{ mm} , W_F = 135 \text{ kN/m}$$

$$M_f = 291.6 \text{ KN}\cdot\text{m}$$

$A_{s(\text{required})}$: $M_f = M_r = 298.8 \text{ kN}\cdot\text{m}$

$$K_r = 1.125 \text{ MPa} \quad \rho = 0.34\% , \rho_{bal} = 3.34\%$$

use 5-20M bars , ($A_s = 5 \times 300 = 1500 \text{ mm}^2$)

Checks:

1. $A_s \leq A_{s_{max}}$, $\rho \leq \rho_{bal}$ $0.42\% < \rho_{bal}(3.34\%)$
2. $A_s \geq A_{s_{min}}$ $1400 > 1265$
3. $\left(\frac{c}{d}\right) < \left(\frac{c}{d}\right)_{max}$ $0.074 < 0.64$
4. $M_r > M_f$ $M_r = 354.5 \text{ kN.m} > M_f = 291.6 \text{ kN.m}$
5. **minimum bar spacing, s** $s = 65 \text{ mm} > s_{min} = 30 \text{ mm}$
6. **Crack Control (z-factor)**

$$z = 23839 \frac{N}{\text{mm}} < 25000 \text{ N/mm (for normal exposure)} \rightarrow \text{OK}$$

c) $h = 800 \text{ mm} > 750 \text{ mm}$

use 4-10M on each side for skin reinforcement $\text{spacing between bars} = \frac{235}{4} = 58.75 \text{ mm}$

d)

