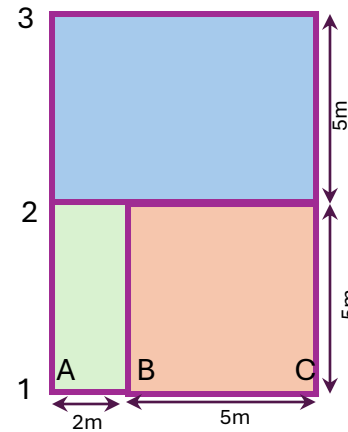


Exam Structural Design - solutions

07/01/2025

Exercise 1 (30 points)

The concrete slab illustrated in the figure below has an overall thickness of 250 mm and is designed to support a variable load of 5 kN/m². Neglect the weight of finishes, and assume the column height is 3.5 m, with the unit weight of both columns and beams being 0.5 kN/m. The unit weight of reinforced concrete is 25 kN/m³. Based on this information, calculate the design loads (ULS) acting on beams A1-B1, A3-C3, B2-C2, and column B2.



$$\text{Slab load} = w = (1.35 \times) (0.25 \times 25) + 1.5 \times 5 \text{ kN/m}^2 = 15,94 \text{ kN/m} \quad (2)$$

$$\text{Column and Beam load} = w = 1.35 \times 0.5 = 0.68 \text{ kN/m} \quad (2)$$

$$\text{A1-B1 } E_{dA1B1} = \text{Slab load} + \text{Beam load} = 81,1 \text{ kNm} \quad (2)$$

$$\text{Slab load} = 2\text{m} \times 2,5\text{m} \times 15,94 \text{ kN/m} = 79,7 \text{ kNm} \quad (1)$$

$$\text{Beam load} = 2\text{m} \times 0,68 \text{ kN} = 1,36 \text{ kNm} \quad (1)$$

$$R_{A1} = R_{B1} = E_{dA1B1} / 2 = 40,5 \text{ kNm} \quad (1)$$

$$\text{B2-C2 } E_{dB2C2} = \text{Slab load} + \text{Beam load} = 401,9 \text{ kNm} \quad (2)$$

$$\text{Slab load} = 5\text{m} \times 5\text{m} \times 15,94 \text{ kN/m} = 398,5 \text{ kNm} \quad (1)$$

$$\text{Beam load} = 5\text{m} \times 0,68 \text{ kN} = 3,4 \text{ kNm} \quad (1)$$

$$R_{B2} = R_{C2} = E_{dB2C2} / 2 = 201 \text{ kNm} \quad (1)$$

$$\text{A3-C3 } E_{dA3C3} = \text{Slab load} + \text{Beam load} = 283,7 \text{ kNm} \quad (2)$$

$$\text{Slab load} = 7\text{m} \times 2,5\text{m} \times 15,94 \text{ kN/m} = 278,95 \text{ kNm} \quad (1)$$

$$\text{Beam load} = 7\text{m} \times 0,68 \text{ kN} = 1,2 \text{ kNm} \quad (1)$$

$$R_{A3} = R_{C3} = E_{dA3C3} / 2 = 141,85 \text{ kNm} \quad (1)$$

$$\text{B2} \quad (1)$$

$$\text{B2-C2} = 201 \text{ kNm} \quad (1)$$

$$\text{B1-B2} = ((1+2,5) \times 15,94 + 5 \times 0,68) \times 0,5 = 25,6 \text{ kNm} \quad (4)$$

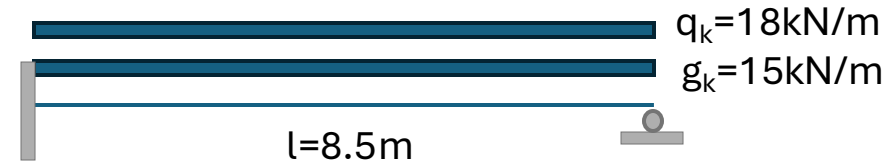
$$\text{A2-B2} = (((2,5+2,5) \times 15,94) + (2 \times 0,68)) \times 0,5 = 40,5 \text{ kNm} \quad (5)$$

$$R_{B2} = (201 + 25,6 + 40,5) \text{ kNm} = 267,1 \text{ kNm} \quad (1)$$

If no one calculate the reaction forces on the beam, then I give +4 bonus..

Exercise 2 (40 points)

A simply supported reinforced concrete beam has a span length of 8.5m, and it is designed with concrete class C25/30 and reinforcement steel B500. The beam is part of an underground parking garage, and it is subjected to uniformly distributed permanent loads of 15 kN/m and variable loads of 18 kN/m. Ignore the beam self-weight. The cross section has a width b of 350 mm, a height of 450mm, and a cover thickness of 25mm. Design the bending reinforcement according with Eurocode 2. Sketch as well the cross section, and the position of the reinforcements.



$$\frac{d_2}{x} \leq 0.38$$

1.

$$w = g_k \gamma_g + q_k \gamma_q = 1.35 \times 15 + 1.5 \times 18 \approx 47.25 \text{ kN/m}^2 \quad (3)$$

2.

$$M_{ed} = \frac{wl^2}{8} = \frac{47.25 \times 8.5^2}{8} \approx 426.7 \text{ kNm} \quad (3)$$

3.

$$M_{Rd} = 0.167 \times f_{ck} \times b \times d^2 = 0.167 \times 25 \times 350 \times 405^2 \approx 239.7 \text{ kNm} \quad (3)$$

4.

$$d = h - c - \phi_{stirrups} - \frac{\phi}{2} \approx 405 \text{ mm} \quad (3)$$

5.

$$z = 0.9d \approx 332.3 \text{ mm} \quad (2)$$

6.

$$z = 0.9d \approx 332.3 \text{ mm}$$

$$M_{ed} > M_{Rd} \text{ (design check)} \quad (1)$$

(Double reinforcement Needed) (2)

$$\frac{d_2}{x} \leq 0.38$$

$$d_2 = c + \frac{\phi}{2} + \phi_{stirrups} = 45 \quad (2)$$

double reinforcement [condition $d_2/x \leq 0.38$] (2)

$$\text{Steel: } A_{s2} = \frac{M_{Ed} - M_{Rd}}{0.87 f_{yk} (d - d_2)}, \quad A_{s1} = \frac{M_{Rd}}{0.87 f_{yk} z} + A_{s2} \quad (3)$$

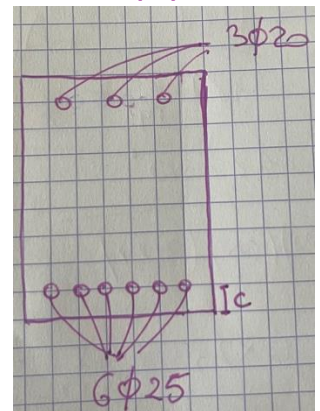
$$\text{with } z = d \left[0.5 + \sqrt{0.25 - 3K'_0/3.4} \right], \quad K'_0 = 0.167, \quad x = (d - z)/0.4 \quad (2)$$

$$A_{s2} = 1194.4 \text{ mm}^2 \rightarrow 3\phi 20 \text{ (942)} \quad (2)$$

$$A_{s1} = 2852.7 \text{ mm}^2 \rightarrow 6\phi 25 \text{ (2945)} \quad (2)$$

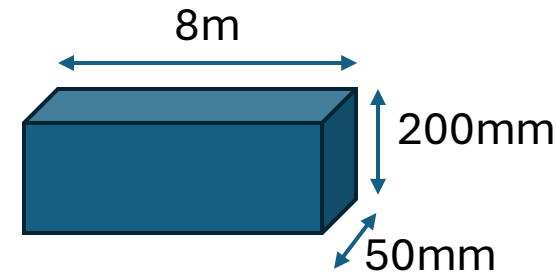
$$\text{Spacing} > \max(\phi, d_{\text{grain}} + 5, 20) \quad (1)$$

$$\text{Spacing } (7+6) \times 25 = 325 \text{ mm} < b \quad (1)$$



Exercise 3 (25 points)

Design a simply supported timber beam with a rectangular cross-section for a roof with a plastered ceiling. The beam is made of C24 solid timber in Service Class 3, with a span of 8.0 m, a permanent load of 2.0 kN/m, and a variable long-term load of 1.2 kN/m. The beam dimensions are: width $b = 50$ mm, height $h = 200$ mm. Consider for a C24 timber a $E_{0,mean} = 11 \text{ kN/mm}^2$. Check the beam for bending and deflection according to Eurocode 5.



- $g_k = 2 \text{ kN/m}$
- $q_k = 1.2 \text{ kN/m}$ (long term)
- $b = 50 \text{ mm}$
- $h = 200 \text{ mm}$
- SC = 3 (solid wood) – roof with plastered ceiling

Design load: (3)

$$w = 1.35 \cdot q_k + 1.5 \cdot q_{lk}$$

$$w = 1.35 \cdot \frac{2 \text{ kN}}{\text{m}} + 1.5 \cdot \frac{1.2 \text{ kN}}{\text{m}} = 4.5 \frac{\text{kN}}{\text{m}}$$

Design Moment (4)

$$M_{yd} = \frac{wl^2}{8}$$

$$M_{Ed} = \frac{4.5 \frac{\text{kN}}{\text{m}} \cdot (8 \text{ m})^2}{8} = 36 \text{ kNm}$$

Bending Strength

(2) $k_{mod} = 0.55$ (long term, SC 3 $\rightarrow$ 0.55)

(4) $X_{md} = \frac{k_{mod} \cdot f_{m,k}}{\gamma_m} = \frac{0.55 \cdot 24 \frac{\text{N}}{\text{mm}^2}}{1.3} = 10.15 \frac{\text{N}}{\text{mm}^2}$ (1)

Bending Stress (6)

$$\sigma_{myd} = \frac{M_{yd}}{I_y} \frac{h}{2} = \frac{wL^2/8}{bh^2/6}$$

$$\sigma_{myd} = \frac{36 \cdot 10^6}{50 \text{ mm} \cdot (200 \text{ mm})^2/6} = 10.8 \frac{\text{N}}{\text{mm}^2}$$

Bending Verification (3)

$$\frac{\sigma_{myd}}{x_{md}} \leq 1 \rightarrow \frac{10.8 \frac{\text{N}}{\text{mm}^2}}{14.1 \frac{\text{N}}{\text{mm}^2}} \approx 0.77 < 1$$

Result: NOT SAFE

(2)