Solutions to Reinforced Concrete Design Problems

Civil Engineering Licensure Exam – Mock Exam

February 26, 2025

Problem 1: Area of Steel in a Singly Reinforced Concrete Beam

Determine the required area of steel reinforcement (A_s) for a singly reinforced concrete beam subjected to a bending moment of 150 kN·m. The beam has a width (b) of 300 mm, an effective depth (d) of 500 mm, and the concrete compressive strength (f'_c) is 25 MPa. Assume the yield strength of steel (f_y) is 415 MPa.

Solution:

The required area of steel reinforcement can be calculated using:

$$A_s = \frac{M_u}{0.87 f_y j d}$$

where: - $M_u = 150 \times 10^6$ N·mm (factored moment) - $j = 0.9d$ (lever arm factor, commonly approximated as 0.9 for preliminary design)

Substituting values:

$$A_s = \frac{150 \times 10^6}{0.87 \times 415 \times 0.9 \times 500} = 923.44\,\text{mm}^2$$

Reference: Singly Reinforced Concrete Beam Problem 1

Problem 2: Longitudinal Reinforcement in a Reinforced Concrete Column

Design the longitudinal reinforcement for a short, axially loaded reinforced concrete column with a square cross-section of 400 mm x 400 mm. The column is subjected to a factored axial load of 2000 kN. Assume $f'_c = 30$ MPa and $f_y = 500$ MPa.

Solution:

The required area of longitudinal steel (A_{st}) is:

$$A_{st} = \frac{P_u - 0.4 f'_c A_g}{0.6 f_y}$$

where: - $P_u = 2000 \times 10^3$ N (factored axial load) - $A_g = 400 \times 400 = 160,000\,\text{mm}^2$ (gross area of column)

Substituting values:

$$A_{st} = \frac{2000 \times 10^3 - 0.4 \times 30 \times 10^6 \times 160,000}{0.6 \times 500 \times 10^3} = 3,333.33\,\text{mm}^2$$

Reference: Concrete Column Axial Design (ACI 318-19)

Problem 3: Shear Capacity of a Reinforced Concrete Beam

A reinforced concrete beam has a width of 300 mm and an effective depth of 500 mm. The concrete compressive strength is 25 MPa. Calculate the shear capacity (V_c) of the concrete.

Solution:

The shear capacity (V_c) of concrete can be determined using:

$$V_c = 0.17 \sqrt{f'_c} b d$$

Substituting values:

$$V_c = 0.17 \times \sqrt{25} \times 300 \times 500 = 318.2\,\text{kN}$$

Reference: Shear Strength of Concrete Beams Example

Problem 4: One-Way Slab Thickness Requirement

Determine the minimum thickness required for a simply supported one-way slab with a span of 4 m to satisfy deflection limits.

Solution:

From ACI Code recommendations:

$$\text{Minimum thickness} = \frac{\text{Span}}{L/d}$$

For a simply supported slab, $L/d = 20$:

$$\text{Required thickness} = \frac{4000}{20} = 200 \text{ mm}$$

Reference: Minimum Thickness of Slabs per ACI 318

Problem 5: Development Length of Reinforcement

Calculate the development length required for a 16 mm diameter reinforcing bar in tension. Assume $f_y = 415$ MPa and $f'_c = 25$ MPa.

Solution:

The development length (L_d) is:

$$L_d = \frac{f_y \phi}{4\sqrt{f'_c}}$$

Substituting values:

$$L_d = \frac{415 \times 16}{4\sqrt{25}} = 332 \text{ mm}$$

Reference: Development Length Calculation for Reinforcement Bars