Solutions to Plastic Analysis and Composite Construction Problems

Civil Engineering Licensure Exam - Day 47

March 7, 2025

Section A: Multiple Choice Questions (MCQs)

1. The plastic moment capacity of a section is determined using:
Answer: (a) The plastic section modulus
Video Explanation: Calculating Plastic Moment Capacity and Shape Factor

2. The shape factor in plastic analysis is defined as:
Answer: (a) The ratio of the plastic moment to the elastic moment
Video Explanation: Shape Factor for Triangular Section

3. A fully plastic hinge forms in a beam when:
Answer: (a) The entire section reaches yield stress
Video Explanation: Plastic Hinge in Structures

4. In a plastic mechanism, the number of plastic hinges required for collapse in a simply supported beam is:
Answer: (a) One
Video Explanation: Collapse Mechanism (Part 1): Plastic Hinge, Virtual Work Method

5. Composite construction typically involves:
Answer: (a) A combination of steel and concrete
Video Explanation: How to Design Composite Beams

Section B: Problem-Solving

1. A steel beam has a plastic section modulus of $Z_p = 600 \times 10^3\,\text{mm}^3$. If the yield strength of steel is 250 MPa, determine the plastic moment capacity.
Solution:

$$M_p = Z_p \times f_y$$

$$M_p = (600 \times 10^3) \times (250) = 150 \times 10^6 \text{ N} \cdot \text{mm} = 150 \text{ kN} \cdot \text{m}$$

Video Explanation: Calculating Plastic Moment Capacity and Shape Factor

2. A beam with an elastic section modulus of $S = 500 \times 10^3 \, \mathbf{mm}^3$ has a shape factor of 1.2. Determine the plastic section modulus.

Solution:

$$Z_p = \phi \times S$$

$$Z_p = 1.2 \times 500 \times 10^3 = 600 \times 10^3 \, \text{mm}^3$$

Video Explanation: Shape Factor for Triangular Section

3. A simply supported beam with a span of 6 m is subjected to a uniform load of 40 kN/m. Determine the collapse load assuming a plastic hinge forms at midspan.

Solution:

$$M_p = \frac{wL^2}{8}$$

$$M_p = \frac{40 \times 6^2}{8} = 180 \, \text{kN} \cdot \text{m}$$

Video Explanation: Collapse Mechanism (Part 1): Plastic Hinge, Virtual Work Method

4. A composite steel-concrete beam has an effective width of 500 mm and a depth of 150 mm. Determine the moment of inertia if the concrete modulus of elasticity is 30 GPa and the steel modulus is 200 GPa.

Solution:

$$n = \frac{E_s}{E_c} = \frac{200}{30} = 6.67$$

$$b' = b \times n = 500 \times 6.67 = 3335 \, \text{mm}$$

$$I = \frac{b'h^3}{12} = \frac{3335 \times 150^3}{12} = 938.44 \times 10^6 \, \text{mm}^4$$

Video Explanation: How to Design Composite Beams

5. A continuous beam has two spans of 5 m each and carries a uniform load of 20 kN/m. Determine the number of plastic hinges required for collapse.

Solution:

For a continuous beam with n spans, the number of plastic hinges required for collapse is:

$$H = n + 1$$

For $n = 2$ spans:

$$H = 2 + 1 = 3$$

Video Explanation: Collapse Mechanism (Part 1): Plastic Hinge, Virtual Work Method