Solutions to Structural Design Methodology Problems

Civil Engineering Licensure Exam – Mock Exam

February 26, 2025

Problem 1: Understanding Allowable Stress Design (ASD) and Load and Resistance Factor Design (LRFD)

Explain the key differences between Allowable Stress Design (ASD) and Load and Resistance Factor Design (LRFD) in structural engineering.

Solution:

Allowable Stress Design (ASD) and Load and Resistance Factor Design (LRFD) are two prevalent methodologies in structural engineering. ASD operates by applying a global factor of safety to account for uncertainties, ensuring that the working stresses remain within allowable limits. In contrast, LRFD employs multiple load and resistance factors to address various uncertainties, focusing on the ultimate strength of materials and structures. This method provides a more uniform level of safety across different loading conditions.

Reference: What's the difference between ASD and LRFD in Structural Design?

Problem 2: Calculating Factor of Safety in Allowable Stress Design

A steel beam is designed using the Allowable Stress Design (ASD) method. The yield strength of the steel is 250 MPa, and the allowable stress is set at 140 MPa. Determine the factor of safety used in this design.

Solution:

The factor of safety (FoS) in ASD is calculated by dividing the yield strength (σ_y) by the allowable stress (σ_{allow}):

$$\text{FoS} = \frac{\sigma_y}{\sigma_{\text{allow}}} = \frac{250\,\text{MPa}}{140\,\text{MPa}} \approx 1.79$$

This indicates that the structure can withstand stresses up to 1.79 times the allowable stress before reaching the yield point.

Reference: Allowable Stress Design - Factor of Safety - Strengths of Materials

Problem 3: Applying Load and Resistance Factor Design (LRFD)

In the LRFD method, a beam is subjected to a dead load of 20 kN and a live load of 30 kN. The load factors for dead and live loads are 1.2 and 1.6, respectively. Calculate the required factored load for design purposes.

Solution:

The factored load (P_u) in LRFD is calculated using the load factors applied to the dead load (D) and live load (L):

$$P_u = 1.2D + 1.6L = 1.2 \times 20\,\text{kN} + 1.6 \times 30\,\text{kN} = 24\,\text{kN} + 48\,\text{kN} = 72\,\text{kN}$$

This ensures that the design accounts for potential increases in load magnitudes, providing a safety margin against possible overloading.

Reference: 1 - ASD vs. LRFD

Problem 4: Determining Allowable Load Using Factor of Safety

A structural component has an ultimate load capacity of 500 kN. If a factor of safety of 2.5 is applied, calculate the allowable load for this component.

Solution:

The allowable load (P_{allow}) is determined by dividing the ultimate load capacity (P_{ultimate}) by the factor of safety (FoS):

$$P_{\text{allow}} = \frac{P_{\text{ultimate}}}{\text{FoS}} = \frac{500\,\text{kN}}{2.5} = 200\,\text{kN}$$

This approach ensures that the component operates within safe stress limits under expected loading conditions.

Reference: Allowable Stress Design - Factor of Safety - Strengths of Materials

Problem 5: Comparing ASD and LRFD in Structural Design

Discuss the advantages and disadvantages of using Allowable Stress Design (ASD) versus Load and Resistance Factor Design (LRFD) in structural engineering projects.

Solution:

ASD offers simplicity and has been traditionally used in structural design, making it familiar to many engineers. However, it applies a uniform factor of safety, which may not adequately address varying uncertainties in different load types. LRFD, on the other hand, provides a more nuanced approach by applying specific load and resistance factors, leading to potentially more economical and uniformly safe designs. The complexity of LRFD calculations can be a drawback, but its precision in safety assessment often outweighs this disadvantage.

Reference: What's the difference between ASD and LRFD in Structural Design?