Finite Element Analysis of Load-Bearing Capacity in Elementary Structural Geometries with Internal Reinforcements

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Abstract:

This study presents a comprehensive Finite Element Analysis (FEA) of three elementary structural geometries with distinct internal reinforcement patterns to evaluate their load-bearing capacity under mechanical loading. The analyzed geometries include a hollow cube with X reinforcement, a hollow cube with orthogonal cross-bracing, and a hollow cube with internal vertical and horizontal plates. Each geometry was subjected to mechanical loading along three principal axes (X, Y, and Z directions) using ANSYS Workbench – Structural Analysis. The results reveal significant variations in stress distribution, total deformation, and factor of safety (FOS) depending on both geometry and load orientation.

The hollow cube with orthogonal cross-bracing demonstrated the most isotropic mechanical behavior, providing uniform resistance across all loading directions. In contrast, the hollow cube with internal plates exhibited directional stiffness, excelling under axial loads but showing vulnerability to off-axis forces. The hollow cube with X reinforcement displayed anisotropic behavior, with enhanced performance along the reinforced diagonal but higher stress concentrations at brace intersections.

These findings highlight the importance of internal reinforcement design and load direction sensitivity in optimizing structural performance. The study suggests further research on nonlinear analysis, material variability, and experimental validation to refine the understanding of load-bearing capabilities and to guide the design of lightweight, mechanically efficient structures.

Keywords:

Elementary Objects, Finite Element Method (FEM), Geometric Optimization, Internal Reinforcement, Load-Bearing Capacity.