

Abstract

The development of construction brings significant environmental challenges, which necessitate the use of modern and sustainable design solutions. Additionally, contemporary structural analyses require the use of fast and efficient methods, especially in the case of multilayered constructions. Traditional numerical methods based on the analysis of three-dimensional FEM models require advanced knowledge and complex software, which, in engineering practice, can be uneconomical. Therefore, it becomes essential to address this issue and develop more accessible and efficient methods for structural analysis.

This work focuses on the analysis and design of multilayered engineering structures. The main issues include the application of a homogenization technique based on the equivalence of deformation energy. The applied methodology enables the replacement of detailed 3D models with equivalent single-layer models, significantly reducing computation time and simplifying the design process without compromising the accuracy of the results. An important aspect of the study was considering nonlinear material properties and the influence of transverse shear, which is crucial for evaluating the mechanical behavior of sandwich panels. An automatic optimization algorithm was also developed, which integrates technical and economic requirements, assisting in the design of complex structures. Furthermore, the sensitivity analysis of design parameters enabled the automatic adjustment of geometry and material properties to meet the defined design criteria.

The results of numerical simulations showed a high agreement between the simplified models and full 3D FEM analyses. The validation of the methodology based on experimental data confirmed its effectiveness and the possibility of practical application in civil engineering. This work makes a significant contribution to the development of efficient computational tools for modern construction, enabling fast and precise design of engineering structures. Moreover, this work contributes to improving the efficiency and environmental sustainability of construction processes.

Keywords:

numerical homogenization, generalized nonlinear constitutive law, multilayered structures, structural optimization, computational validation

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