Three-dimensional topology optimization of microstructure for composites applying a decoupling multi-scale analysis

Junji Kato[1)], Daishun Yachi[2)], Kenjiro, Terada[1)], Takashi Kyoya[2)]

[1)] International Research Institute of Disaster Science, Tohoku University, Japan

[2)] Department of Civil Engineering, Tohoku University, Japan

6-6, Aoba, Aramaki, Aoba-ku, SENDAI 980-8579, Japan

E-mail: jkato@civil.tohoku.ac.jp

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Abstract: The present study addresses three-dimensional topology optimization of a micro-structure for composites considering the macroscopic structural response, applying a decoupling multi-scale analysis based on a homogenization approach. It is well known that the mechanical behavior of composite materials depends on the geometric properties of the micro-structure. Thus, the structural performance of a macro-structure could be maximized by optimizing the micro-structures. In this study the stiffness of a macrostructure is maximized with a prescribed material volume of constituents of the microstructure in terms of a gradient-based optimization strategy. For this purpose, multi-scale analysis is necessary for the structural analysis. As the general multi-scale analysis methods solve micro- and macro-scale BVPs simultaneously by reciprocal exchange in order to achieve accurate solution on a micro-macro two-scale BVP, they are considered theoretically established and reliable. However, these approaches are rarely applied to actual designing because they are theoretically difficult to understand and the computational costs are enormous.

Taking this situation into account, we apply a *decoupling multi-scale analysis* for this optimization problem although only a linear elastic material model is assumed. This method is intended to reduce the computational costs by introducing an approximate approach called *numerical material tests* (NMTs). This research proposes an optimization procedure and its sensitivity analysis considering the decoupling multi-scale analysis.

It is verified from a series of numerical examples that the proposed method has great potential for microscopic advanced material design.