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Multiphase topology optimization for fiber reinforced composites with damage

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ABSTRACT

The present study addresses an optimization strategy for fiber reinforced composites as an example in particular applying it to textile fiber reinforced concrete (FRC) with emphasis on its special failure behavior. FRC is an advanced material that consists of a concrete matrix and glass, carbon or aramid fibers. Since both concrete and fiber are brittle materials a prominent objective for FRC structures is concerned with the improvement of ductility. Despite above unfavorable characteristics of the individual constituents the interface between fiber and matrix plays a substantial role in the structural response eventually leading to the necessary ductility of the composite. This 'composite effect' is strongly related to the material behavior of the interface and the material layout on the small scale level, e.g. fiber size, length and different fiber material combinations. In addition to those material properties the geometry of fiber reinforcements has a large influence on the total structural response on a macroscopic level.

The purpose of the present study is to improve the structural ductility of FRC structures applying structural optimization with respect to both small scale material and/or significant macroscopic geometrical parameters. The small scale material parameters are controlled by a multiphase topology optimization (Sigmund et al. [1]). This methodology has been extended to a damage model for FRC by Kato et al. [2]. In addition to this multiphase topology optimization shape optimization is introduced for the fiber geometry. The definition of the fiber layout is independent from the Finite Element Mesh.

The nonlinear failure behavior of matrix, fiber and interface is described by a damage model. For the optimization problem a gradient-based optimization algorithm is applied. The sensitivity analysis considers both, the multiphase topology and the shape optimization. Finally, the performance of the proposed method is demonstrated in a series of numerical examples.

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