6th European Conference on Computational Mechanics (ECCM 6)
7th European Conference on Computational Fluid Dynamics (ECFD 7)
11-15 June 2018, Glasgow, UK

Topology optimization of geotechnical designs involving ultimate limit states

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Keywords: *Topology optimization, Ultimate limit states, Geotechnical design*

Numerical optimization of the shape and topology of structures provides a valuable tool for engineers in an early design stage. It results in a first design proposal that can be further refined during different design iterations. For geotechnical applications (surface and deep foundations, earth retaining walls,...), an important design requirement is sufficient safety against failure in the ground. Therefore, the correct incorporation of these ultimate limit states in shape and topology optimization should lead to better initial designs that may reduce the amount of subsequent manual design iterations.

This contribution presents a computationally efficient approach for the topology optimization involving ultimate limit states for geotechnical designs. The ultimate limit states are analysed using limit analysis, which allow for the direct computation of failure mechanisms as a convex optimization problem [1]. The topology optimization employs a filtered Solid Isotropic Material with Penalization (SIMP) approach to select soil or grout/concrete within a design domain. This results in a nested optimization problem: a high level non-convex (topology) optimization problem accounting for design constraints, with ultimate limit states that are obtained as the solution of a low level convex optimization problem. The high-level topology optimization problem is solved using the method of moving asymptotes (MMA), where the required sensitivites with respect to the SIMP design variables are easily obtained from the solution of the lower level optimization problem.

The methodology is applied to a number of geotechnical design problems, such as the design of jet-grouted foundations and earth-retaining gravity walls. In each case, the volume of the foundation is minimized for a target bearing capacity and/or safety factor against sliding failure in the ground.

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