Computational Simulation of Soil Freezing: Multiphase Modeling and Strength Upscaling

Doctoral defense by MENGMENG ZHOU

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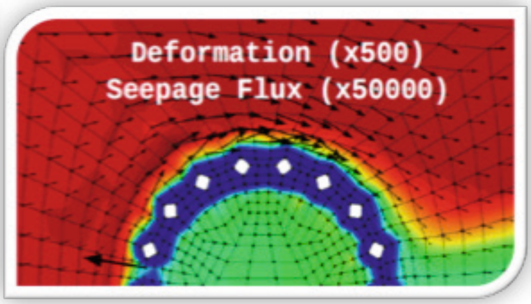
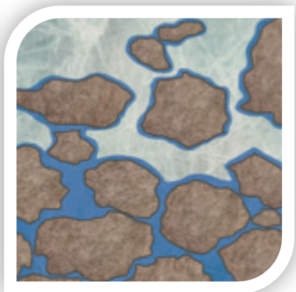
In geotechnical applications of artificial ground freezing, safe design and execution require a correct prediction of the coupled thermo-hydro-mechanical behavior of soils subjected to freezing. In the context of thermoporoplasticity, a three-phase Finite Element model of freezing soils is presented, considering solid particles, liquid water and crystal ice as separate phases, and mixture temperature, liquid pressure, and solid displacement as primary field variables. Through three fundamental physical laws and corresponding state relations, the model captures the most relevant couplings between the phase transition, the liquid transport within the pores, and the accompanying mechanical deformation. For the description of the poroplastic mechanical behavior of the soil model, the enhanced Barcelona Basic Model is adopted within a unified effective-stress-based framework. In particular for the prediction of the temperature- and porosity-dependent strength criterion of freezing soils, a novel multi-scale strength homogenization procedure is proposed, which allows to determine the macroscopic cohesion and frictional coefficient based on the current state of the microstructure of freezing soils.The performance of the proposed model is demonstrated by re-analysis of a soil freezing test and AGF processes during tunneling.





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