THM Experiment for the Investigation of Freeze-Thaw Processes in Soils and Grouting Materials

Jan Christopher Hesse¹², Markus Schedel¹², Bastian Welsch¹², and Ingo Sass¹²
¹Technische Universität Darmstadt, Geothermal Science and Technology, Darmstadt, Germany (hesse@geo.tu-darmstadt.de)
²Darmstadt Graduate School of Excellence Energy Science and Engineering, Darmstadt, Germany

Freeze-thaw processes induced in the vicinity of borehole heat exchangers (BHE) as a result of operating temperatures below 0 °C can significantly affect the compound structure consisting of the BHE pipes, the cement-based grouting material as well as the surrounding soil. The hydraulic integrity of such systems is not ensured anymore and its thermal efficiency could be impaired. However, the knowledge on freezing and thawing processes in porous media, such as the grout and unconsolidated rock materials, is still incomplete. The content of unfrozen water has a strong impact on material properties influencing the overall heat and mass transfer processes. Moreover, freezing strongly depends on various boundary conditions such as soil type or pore water chemistry. Accordingly, it is essential to have adequate information about the freezing interval for different boundary conditions, which describe the transition from pure liquid water to the ice phase and vice versa.

Therefore, a thermo-hydraulic-mechanical (THM) experiment has been developed and is used to gain a more detailed insight into freezing processes in artificial grouts and unconsolidated rock materials. It consists of a modified triaxial test system, which can carry cylindrical samples with a diameter of up to 100 mm and a height of up to 200 mm. A confining pressure of up to 16 bar can be gained by a plunger system. The confining pressure liquid (water-glycol-mixture) can be tempered down to -25 °C and is used to induce freezing conditions on the lateral surface of the sample. Mechanical parameters such as the freeze pressure are recorded by an axial load sensor and a displacement sensor. Besides, the radial deformation can be observed by the volume displacement of the confining liquid. Moreover, the hydraulic conductivity of the sample is determined according to DIN EN ISO 17892 (2019). The fluid temperatures during the flow-through experiment can be varied between 5 °C and 25 °C to represent natural groundwater temperatures. In addition to that, the freeze-thaw experiment is equipped with an ultrasonic measurement device: In the observed temperature range, the wave velocity in solid particles is constant and not affected by temperature changes. However, with descending temperature, the ice content increases, which leads to an improved cross-linking of the solid soil particles. As a consequence, the bulk P-wave velocity increases with decreasing unfrozen water content. Hence, this relationship can be used to determine the content of unfrozen water during a freeze-thaw cycle.
At this time, the first experiments are conducted with this novel device. Consequently, initial results will be presented at the conference. Moreover, the results of the THM experiments will be implemented in numerical models, which allow for an upscaling of the experimental findings to real scale applications.