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## Experimental Investigation of Freeze-Thaw Processes in Soils and Grouting Materials

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Freezing and thawing in the subsurface is often related to complex technical handling of possible influences on the engineered structures (e.g. permafrost or geothermal heat pumps). Freeze-thaw processes in the vicinity of borehole heat exchangers can significantly impair the system. However, for groundwater protection and thermal efficiency, the hydraulic and thermal integrity of such systems must be permanently ensured for the complete operation time. Detailed knowledge on freeze-thaw processes in porous media, such as soils or geotechnical grouts, and the driven parameters, is still pending. Freezing in porous media does not occur as a sudden transition from pure liquid water to the ice phase, but rather within a freezing interval strongly depending on various boundary conditions such as soil type or pore water chemistry. As the content of frozen and unfrozen water has a strong impact on material properties, it is essential to have suitable information about the different factors influencing freezing processes as well as the thermo-hydraulic-mechanical (THM) effects on porous media due to phase change. Thus, a THM laboratory experiment was developed and built to gain more knowledge on freeze-thaw processes and their effects on soil and grouting materials. The experiment consists of a modified triaxial test, enabling for controlled temperature and hydraulic flow conditions, that is combined with an ultrasonic measurement device to determine the unfrozen water content.

In this contribution, results of the THM experiment are presented, whereas the following parameters were investigated: The freezing interval using P-wave velocity, freezing pressure as well as axial and radial volume expansion due to ice formation as well as the influence of hydraulic flow on the ice formation. First, benchmark experiments were conducted on well-characterized solid rock samples to avoid any influence of a variable sample pore structure during the experiments. Further experiments focused on the investigation of soil samples of different texture classes. For upscaling to real scale applications, the experimental findings will be implemented in numerical models.