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Ice crystallization and mechanical damage at the pore scale

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Ice crystallization and mechanical damage at the pore scale
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Abstract
Frost in wintry weather conditions is one of the major causes of the degradation of roads, buildings and outdoor artworks that are all porous media and are prone to damaging. With the decrease of the temperature, the water present in the porous structure can crystallize; the formation of ice in the pore network or in cracks subsequently results in mechanical damage such as crack propagation or the delamination of the stone. The effect of ice crystallization in unconsolidated porous materials, known as frost heaving, results in an upward swelling of soils during freezing. Previous studies on freeze/thaw cycling in porous media have been done mostly on the macro and mesoscale. However, the detailed mechanism by which the damaging occurs is still ill understood; for instance, the mechanical properties of the ice and most porous media are such that one would expect the ice to break, and not the porous medium to be damaged.
Here, we present our results on ice crystallization in confinement at the microscale and investigate the conditions under which mechanical damage develop. In order to do so, micro scale experiments have been performed in a model microcrack/pore. Using glass micro capillaries of various sizes, parameters that cause fracture in the glass capillaries during freeze /thaw cycles are investigated; we are able to freeze water droplets inside the micro capillaries and simultaneously image the freezing and measure the deformation of the capillaries upon freezing, over multiple cycles. From the deformation of the capillaries we can estimate the pressure build-up by the ice in the confinement. The experimental results are compared with theoretical arguments in order to better understand the frost action at microscale on the resulting macroscale mechanical damage. The hoop stress responsible of the breaking of a single pore has been calculated considering the pressures induced by the crystallization process and the volume expansion of liquid water turning into ice.
Finally,we will discuss the importance of contact angle, volume of the confined water as well as the cycling on fracture observed in microcapillaries.

Time Block Preference

Time Block B (14:00-17:00 CET)

References

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