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Ice crystallization in porous building materials: assessing damage using real-time 3D monitoring

Maxim Deprez (1), Tim De Kock (1), Geert De Schutter (2), and Veerle Cnudde (1)

(1) Ghent University, PProGRess-UGCT, Department of Geology, Ghent, Belgium (maxim.deprez@ugent.be), (2) Ghent University, Magnel Laboratory for Concrete Research, Department of Structural Engineering, Zwijnaarde, Belgium

Frost action is one of the main causes of deterioration of porous building materials in regions at middle to high latitudes. Damage will occur when the internal stresses due to ice formation become larger than the strength of the material. Hence, the sensitivity of the material to frost damage is partly defined by the structure of the solid body. On the other hand, the size, shape and interconnection of pores manages the water distribution in the building material and, therefore, the characteristics of the pore space control potential to form ice crystals (Ruedrich et al., 2011). In order to assess the damage to building materials by ice crystallization, lot of effort was put into identifying the mechanisms behind the stress build up. First of all, volumetric expansion of 9% (Hirschwald, 1908) during the transition of water to ice should be mentioned. Under natural circumstances, however, water saturation degrees within natural rocks or concrete cannot reach a damaging value. Therefore, linear growth pressure (Scherer, 1999), as well as several mechanisms triggered by water redistribution during freezing (Powers and Helmuth, 1953; Everett, 1961) are more likely responsible for damage due to freezing. Nevertheless, these theories are based on indirect observations and models and, thus, direct evidence that reveals the exact damage mechanism under certain conditions is still lacking. To obtain this proof, in-situ information needs to be acquired while a freezing process is performed. X-ray computed tomography has proven to be of great value in material research. Recent advances at the Ghent University Centre for Tomography (UGCT) have already allowed to dynamically 3D image crack growth in natural rock during freeze-thaw cycles (De Kock et al., 2015). A great potential to evaluate the different stress build-up mechanisms can be found in this imaging technique consequently. It is required to cover a range of materials with different petrophysical properties to achieve a correct assessment of the acting damage processes. Natural building stones tend to have an accessible open pore structure, whereas concrete is significantly less permeable and has large gel pores. Three sedimentary rocks (Bentheimer sandstone, Savonnières limestone and a classic Turkish travertine) and two types of concrete with a different water-cement ratio (0.6 and 0.5) are included in this research. With X-ray CT two approaches can be considered. First, an attempt directly to monitor the transition of water into ice can be performed. Secondly, the location of the induced micro-cracks within the pores or pore throats can possibly indicate which mechanism has caused them. Moreover, the retrieved CT data will be compared to different proxies for ice formation, such as length and temperature changes during freezing. This research is supported by FWO, project 3G004115.

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