Real time 3D monitoring of frost damage in porous building materials

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ABSTRACT

At middle to high latitudes, frost weathering is one of the main causes for degradation of porous building materials. Therefore, during the last century, a lot of effort was put into assessing and quantifying the damage caused by ice crystallization through frost-thaw cycle and continuous freezing experiments (Matsuoka and Murton, 2008). However, to make a correct assessment of the damage, it is important to have a good knowledge on the acting damage mechanisms and how it translates to a pressure build-up in the pore space of the material. Several theories were deduced concerning the stress build-up, such as the hydraulic pressure theory of Powers (1945) and the osmotic pressure theory of Powers & Helmuth (1953). The capillary growth pressure theory of Everett (1961), however, is nowadays accepted as the most likely damaging mechanism. Nevertheless, direct evidence that reveals the damage mechanism is still lacking. Multiple approaches have been exerted to deliver this evidence, but imaging by using X-ray micro computed tomography (µCT) was only applied limitedly. The capability of visualizing the freezing process in three dimensions was exploited recently and showed great promise for further research (De Kock et al., 2015). Depending on the structure and connectivity of the pores, different damage mechanisms could be acting. Natural building rocks tend to have an accessible open pore structure, whereas concrete is significantly less permeable and has large gel pores. To make a correct assessment of the mechanism it is required to cover these materials and therefore, 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) were included in this research. By performing dynamic µCT on those samples at the Ghent University Centre for Tomography (UGCT) and using a cooling stage around the sample of interest, high-resolution three-dimensional images during freezing are obtained. Afterwards, two approaches can be considered to deliver the evidence necessary to confirm the damage mechanisms. 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.

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