DYNAMIC X-RAY CT TO MONITOR WATER DISTRIBUTION WITHIN POROUS BUILDING MATERIALS: A BUILD-UP TOWARDS FROST-RELATED EXPERIMENTS

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Summary: Several porous building materials are exposed to dynamical X-ray CT experiments to unravel the water distribution pattern. This way, a first evaluation of the location of the moisture distribution within the pore-space can be made. Eventually, the goal is to work towards real-time monitoring of the initiation of frost-induced micro cracks and to assess the acting damage mechanisms.

1. INTRODUCTION

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 equals 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 manage the water distribution in the building material and, therefore, the characteristics of the pore space that control the formation of ice crystals [1]. 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 % [2] during the transition of water to ice should be mentioned. Under natural circumstances, however, water saturation degrees within natural stones or concrete rarely reach a damaging value. Therefore, linear growth pressure [3], as well as several mechanisms triggered by water redistribution during freezing [4, 5] are more likely responsible for the stress build-up due to frost action. Nevertheless, these theories are based on indirect observations and models, hence direct evidence revealing 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. Lab-based 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 [6]. A great potential to evaluate the different stress build-up mechanisms can be found in this imaging technique consequently. A first logical step for this matter is to characterize the water distribution in the materials of interest in unfrozen conditions. Furthermore, as the capillary forces change with the pore sizes, water redistribution over time is monitored.

2. EXPERIMENTAL METHOD

The water uptake and distribution, as well as frost susceptibility, is strongly dependent on the properties of the pore space. Hence, a range of materials with different petrophysical properties is necessary included in this research. Natural building stones tend to have an accessible open pore structure, whereas concrete is significantly less permeable and has induced air voids. Three sedimentary rocks (Bentheimer sandstone, Savonnières limestone and a classic Turkish travertine) with different pore networks and two types of concrete with a different water-cement ratio (0.6 and 0.5) are included in this research.

The Environmental Micro-CT (EMCT) scanner at UGCT is a gantry-based system, able to monitor processes happening within a time range going from 12 seconds up to hours. The maximal obtainable spatial resolution of

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the setup is below 5 µm [7]. To enhance the contrast between moisture and air, a highly attenuating doping agent (CsCl) is added to the water. While mounted on the scanner, one surface of the sample is exposed to the doped water solution and the capillary absorption is visualised over fixed time steps. After the solution reached the top of the sample, it is dismounted and closed off to keep the moist level within the sample constant. Afterwards, the same sample is imaged in 3D again. Repetitive imaging will show how the water redistributes over time, closed off from any water source. Preferential locations of the water indicate where in the pore space one should focus on while freezing experiments are performed.

3. RESULTS

Preliminary results for the Noyant Limestone [6] show the capillary uptake could be visualised very well (figure). The addition of CsCl to the moist clearly causes pixels in the reconstructed dataset to have a larger attenuation. Differential imaging [8] leads to the ability to distinguish water-filling pores from empty ones and the solid surroundings over time. Image analysis on 3D volumes of this rock made on different time steps lead to an assessment of the preferential flow path of the moist and a final moist distribution.

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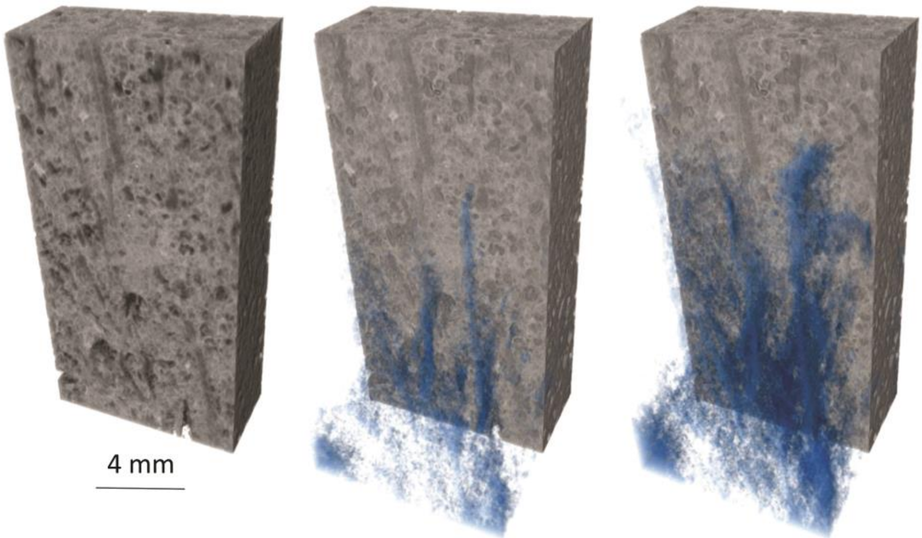

Figure: A cropped reconstructed volume of Noyant limestone before and during two different time steps in a capillary uptake experiment. The moisture is indicated in blue [6].