Visualization of fracture formation within a porous limestone

M.A. Boone [(a)(1)], T. De Kock [(a)], J. Dewanckele [(a)(b)], V. Cnudde [(a)(b)], M.N. Boone [(b)], D. Van Loo [(b)] , P. Jacobs [(a)(b)], E. Van de Casteele[(d)]

(1) marijn.boone@ugent.be
(a) Research Group Sedimentary Geology and Engineering Geology, Department of Geology and Soil Science, Faculty of Sciences, Ghent University, Krijgslaan 281/S8, 9000 Gent, Belgium.
(b) Centre for X-ray Tomography (UGCT), Department of Subatomic and Radiation Physics, University Ghent, Proeftuinstraat 86, 9000, Gent, Belgium
[(d)] SkyScan, Kartuizersweg 3B, 2550, Kontich, Belgium

Aims. In the following study we try to get a better insight into the physical weathering processes that occur within porous natural building stones. The influence of weathering processes on building stones is mainly controlled by the internal structure of the rock and its surrounding environment (Brimblecombe et al., 2006; Dreesen et al., 2004). Therefore we try to visualize the changes of the internal structure of the natural building stone during different phases of the weathering process.
We focussed on crack formation within the rock caused by sequential freezing and thawing of water saturated limestone and by uniaxial confining pressure as weathering processes. Water in combination with sequential freezing causes pressure to build up in the pores of the limestone and results eventually into fractures within the rock fabric (Marchand et al., 1995). Where these fractures form and how they grow depends on the size, distribution, structure and interconnectivity of the pores and on the constitution of the rock fabric. External pressure produces stress upon sides of the limestone, causing small deformations and finally the formation of fractures. The aim of the study is to visualize those deformations before, during and after the weathering processes with X-ray computed tomography and to try to deduct the origin of these fractures in the rock fabric.
Previous studies on sequential freezing (de Argandona, Rey et al. 1999; Rodriguez-Rey, de Argandona et al. 2004; Zhang, Lai et al. 2004) and on confining pressure (Ge, Ren et al. 2001; Besuelle 2004) on other geomaterials combined with X-ray CT have already proven to be successful and show that X-ray CT is one of the most powerful tools to investigate weathering processes in depth.

Method. The building stone that was used is the Noyant Fine, a limestone that consists mainly out of fossil fragments (foraminifers) held together in a micritic matrix. This building stone was chosen based on previous studies which revealed a high sensitivity to frost weathering and a low pressure resistance.
Five cylindrical samples of 15 mm in length and a diameter of 9 mm where used for the frost tests. The samples were scanned with the micro-CT scanner at the Centre for X-ray Tomography at Ghent University (UGCT), before and after each freeze-thaw cycle (Masschaele et al., 2007). First, the samples were saturated by submersion in water and afterwards frozen at -15°C for a period of 5-6 hours.
Shorter samples in length, but with the same diameter, were used for the compression tests. To compress the samples a SkyScan Material Testing Stage of 440N was used in combination with the SkyScan 1172 high-resolution micro-CT scanner. The samples were scanned before and during loading and also after fracture took place.

Results. The fractures that are formed in the limestone by the freezing processes are located near zones with a low porosity and at zones were microcracks were already present. No fractures were located around larger pores. The water, located in those pores, had enough space to expand without inducing new cracks.
The pressure test show that the limestone reacts elastic between 0N and 300N to 440N. Above 300N to 440N cracks form and grow in the building stone. The fractures show no clear pattern and initiate at a wide range of loading forces. This is probably caused by the heterogeneous internal structure of the limestone.

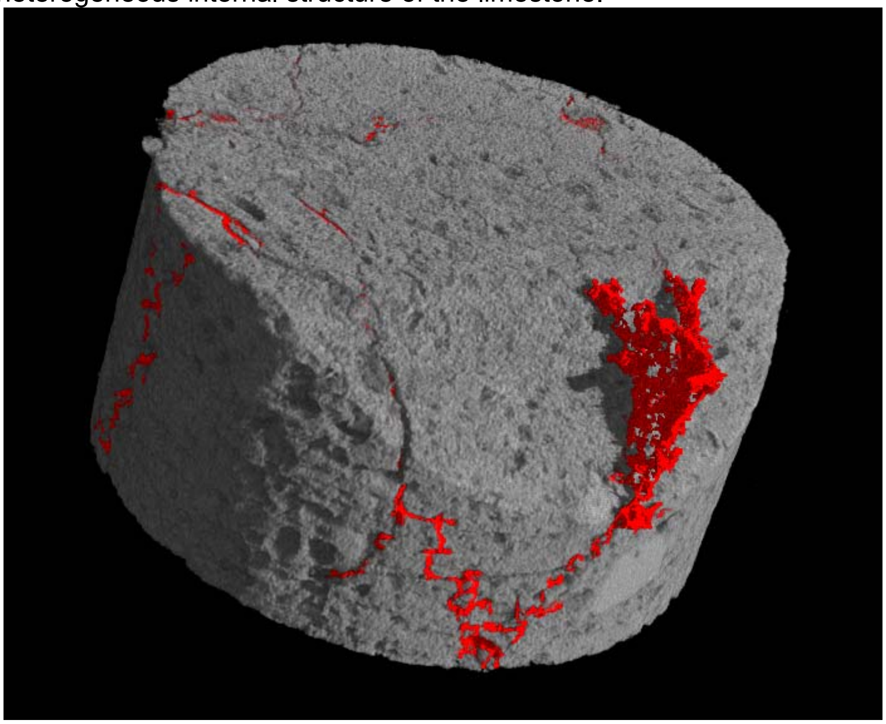

Figure: Fractures formed by uniaxial confining pressure in the Noyant Fine limestone

Conclusion. The Noyant Fine limestone has a heterogeneous internal structure and has a poor frost resistance. During cyclic freezing and thawing of the limestone, new fractures are growing from already present microfractures within the rock and are also induced in the regions with smaller pores. The micro-CT technique proves to be a powerful monitoring tool providing new insights on weathering processes which are crucial for the characterisation and conservation of building materials (Cnudde et al., 2006).

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