Decay of historic stone masonry due to thermal cycles and salt crystallisation: new challenges in a changing environment

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Many of Italian and Scottish iconic monuments are built using porous sedimentary rocks. Increasing levels of extreme weather events can lead to the increase of degradation of the historic fabric and loss of structural integrity through processes such as increased water penetration, more frequent freeze-thaw cycles and salt-induced decay.
Although geographically distant, the historic buildings in the two cities of Bari (Apulia) and Edinburgh (Scotland) are exposed to similar threats, i.e. both cities are located in the vicinity of sea water that exposes stone masonries to salt-induced decay (chemical weathering). At the same time, climate changes would expose the rock materials to unusual and unprecedented temperature conditions. In particular, temperature variations are responsible for physical damage of stonework of valuable heritage sites. For instance, freeze-thaw cycles in cold climates (Scotland), and expansion-contraction cycles in warm climates (Apulia), are responsible for inducing cracking in the stone masonry of many historical buildings. Furthermore, physical degradation (i.e., thermal cracking) often acts in combination with salt crystallization damage as the cracks caused by thermal damage would allow saline-rich fluids to penetrate in the inner parts of rock materials further exposing them to chemical weathering. Laboratory simulation of thermal and chemical conditions responsible for the degradation of historic stoneworks can actively contribute to conservation management plans. The combination of advanced analytical and imaging techniques can provide powerful tools for understanding and evaluating the damages occurring to historic stone materials exposed to the changing climate.
In this study two rock types have been selected and compared, i.e. a limestone (Calcare di Bari) and a sandstone (Binny Sandstone), which are representative and widely used building stones in the two areas of Bari and Edinburgh, respectively. Structural and elemental analytical techniques were combined with advanced analytical tools and modern

3D-imaging methods, i.e. computed tomography (CT) and micro computed tomography (μ-CT), laser-induced breakdown spectroscopy (LIBS), in order to study the degradation processes responsible for the damage of stone masonries in these two cities.
The mechanical damage due to freezing/thawing cycles and crystallisation of NaCl rich brines (salinity of about 3.5% (35 g/l) within these historical stones masonry has been tested and modelled by CT, μ-CT and LIBS, which provided new insights on the weathering processes damaging these stone buildings. In particular, pre- and post-imbibition CT and μCT acquisitions were conducted to visualize and describe salt crystallization patterns both at specimen surfaces and inwardly, moreover, it has been possible to evaluate the occurrence of mechanical damages such as cracks and particles detaching after the testing procedure. The CT 3D-rendering allowed to visualize the spatial distribution of porosity within the selected rock types which allowed to measure the percentage of connected pores representing preferential channels for water/fluid infiltration and percolation responsible for the stones' weathering degradation. Furthermore, the detection, identifications and microchemical mapping of the elemental composition of the mansory rock samples achieved by handheld LIBS analysis in real-time in the field have provided useful additional information on the physical processes that may occur in these stones weathering.

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