ABSTRACT

The work presented in this thesis focuses on the understanding of the natural and simulated chemical and mechanical weathering of frequently used building stones such as marble, limestone and sandstone, and the characterization of their deterioration. The knowledge gained about the vulnerability of the stones in terms of weathering is important for the diagnostics of old stones and is beneficial in the selection of stones for repair and new constructions. The research work comprises of three main topics: (i) the investigation of chemical corrosion of the thin sections of the stones in simulated humid air containing mixture of SO_2 and NO_2 gases; (ii) the investigation of physical weathering of the stones due to cyclic temperature changes by analysis of initial micro-cracking and porosity characteristics; and (iii) the evaluation of the efficacy of impregnation and consolidation agents on the physical and chemical durability of the stones.

Results are presented from a novel approach to the study of stone deterioration. Thin stone sections are introduced as the material used for experimental purposes. The use of thin sections facilitates observations of the effect of individual pollutants on the stones in relation to the mineralogy and structure of a stone. Observations of the initial corrosion of the stone surfaces indicate variations in the lateral distribution of efflorescence, its intensity and shape among and within the samples. The mineralogy, grain shape and size, mineral defects and existence of cracks and pores all influence the reactivity of the substrate. The most vulnerable areas and places where the corrosion starts, on the calcitic samples are the triple grain junctions and grain boundaries, whereas on the dolomitic marbles are cracks, pores and calcitic micro-crystal surfaces. A qualitative difference in surface sulphite stability, calculated by the first-principles density functional theory, at calcite and dolomite, favoring the former, implies that calcitic micro-crystals embedded in a dolomitic matrix act as sinks in the surface sulphition process, controlled by SO_2 diffusion.

Impregnation diminishes the corrosion rate and increases the mechanical strength of the calcareous stones. It also has a mitigating effect on the inter-granular decohesion due to heat exposure. Impregnation of the quartzitic sandstone has only a negligible effect. However, the mechanical properties of the calcitic sandstone are improved by impregnation.

The inter-granular decohesion in calcareous rocks exposed to heat starts at temperatures as low as 50° C. This should be considered when drying test specimens for all standardized tests. The calcitic marble is more susceptible to temperature change than the dolomitic marble. The use of gas adsorption and fluorescence microscopy provides consistent information about the initial cracking of the stones. The differential thermal expansion/contraction associated with different mineralogical and textural properties of the stones is primarily responsible for the increase in number of pore spaces and their magnitude. The results demonstrate that the largest expansion occurs along the grain boundaries, suggesting that that the durability of a fine-grained sample is more sensitive to temperature change than the coarse-grained since the total volume of grain boundaries increases with falling grain size. Thermal expansion at low humidity is apparent for both marbles. The permanent thermal expansion is, however only significant in calcitic marble.

Keywords: weathering, marble, limestone, sandstone, efflorescence, porosity, impregnation agents, thermal treatment