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Thermally and load induced stresses in marbles

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Introduction

Marbles are frequently used as a natural building stone for constructive and decorative matters in cultural heritage. However, their lifetime is frequently very limited. The initial stage of marble weathering is supposed to be controlled by thermal microcracking. Due to the anisotropy of the thermal expansion coefficients of calcite, the main rock forming minerals in marble, stresses are caused which lead to thermally-induced microcracking, especially along the grain boundaries. Subsequently, also chemical and biological weathering may increase. The so-called “granular disintegration” is a frequent weathering phenomenon observed for marbles. The controlling parameters are the size, the shape and the orientation of grains (e.g. Tschegg et al. 1999, Royer-Carfagni, 1999; Weiss et al. 2002, 2003).

Methods

We use a finite-element approach to constrain magnitude and directional dependence of thermal stresses in marbles leading to grain boundary fractures. Therefore, the effects of the grain-to-grain orientation and bulk lattice preferred orientation (here referred to as texture) are considered. Textures are either generated for microstructure consisting of a large number of grains (˜900) or measured on real samples using electron backscattered diffraction (EBSD). EBSD measurements allow the exact determination of the complete orientation of individual grains.

Results

The first step for the simulations considers both, the bulk texture and the misorientation distribution function (MDF) on a synthetic basis. The three different main types of

MDF's (high, low and random MDF) cause different thermal stresses upon heating. In the next step, real textures from different marbles used as natural building stones obtained from EBSD are compared with the synthetic ones. The resulting thermal microcracking and bulk rock thermal expansion anisotropies are validated. It is evident that thermal degradation depends on the texture. Strongly textured marbles exhibit a clear directional dependence of thermal degradation and a smaller bulk thermal degradation than randomly oriented ones. However, it is well known that the misorientation distribution function, i.e. the orientation relationships between adjacent grains, strongly affects internal stresses as a consequence of temperature increase. So far, the effect of different load conditions and of in-situ stresses (of geological origin) has not been considered in simulations. Numerical models mainly assume a stress free state at the beginning of the simulation. Thus, the effect of preloads on magnitude and orientation of internal stresses is validated which may lead to microcracking and, consequently, material failure in time. The results give indications for a better understanding of material damage on-site and associated conservation measures. Furthermore, a quantitative assessment between load and temperature induced stresses is possible.

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