Numerical simulation of volumetric expansion of stone in historical buildings

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Abstract

The Nidarosdomen cathedral is the largest Gothic edifice in Northern Europe, and as perhaps the most important part of the Norwegian cultural heritage, it is subjected to continuous restoration. The so called King's entrance of the Cathedral, a doubly curved vault gate to the Choir, shows severe deterioration by cracking.
In a study to find plausible reasons for the degradation, the entrance was laser-scanned, modeled in a FEM context and investigated by linear-elastic analyses with DIANA.
The study revealed two possible reasons for the crack-pattern in the entrance walls; shear deformations due to differential settlements and/or tilting of the choir-wall. The analyses did however not justify the observed large crack-openings.
When rebuilding the King´s entrance, in the 1950´s, a particular type of soapstone, the Grytdal-stone was used. Later on, the Grytdal-stone has shown to be sensitive, especially with respect to moisture.
When exposed to moist, the Grytdal-stone expands significantly, this has been proved by experimental testing. The results of simple expansion experiments on the Grytdal-stone have been implemented by means of temperature dependencies in linear elastic as well as nonlinear/cracking models in Diana.
The analyses indicate that expansion of intrinsic Grytdal-stone in the gate, as well as in the walls of the King´s entrance, may be the reason for the extensive observed cracking.