Nanoparticles can save historic buildings made from porous rock

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Restoration work at St. Stephen's cathedral in Vienna. Credit: Archiv der Dombauhütte St. Stephan

Many historical buildings were built of sandstone, including Vienna's St. Stephen's Cathedral. Sandstone is easy to work with, but does not withstand weathering. It consists of sand grains that are relatively weakly bonded to each other, which is why parts of the stone crumble away over the years, often requiring costly restoration.

However, it is possible to increase the resistance of the stone by treating it with special silicate nanoparticles. The method is already being used, but what exactly happens in the process and which nanoparticles are best suited for this purpose has been unclear until now. A research team from TU Wien and the University of Oslo has now been able to clarify exactly how this artificial hardening process takes place through elaborate experiments at the DESY synchrotron in Hamburg and with microscopic examinations in Vienna. The team also determined which nanoparticles are best suited for this purpose. Their study was published in *Langmuir*.

An aqueous suspension with nanoparticles

"We use a suspension, a liquid, in which the nanoparticles initially float around freely," says Prof. Markus Valtiner from the Institute of Applied Physics at TU Wien. "When this suspension gets into the rock, then the aqueous part evaporates, the nanoparticles form stable bridges between the sand grains and give the rock additional stability."

This method is already used in restoration technology, but until now, it was not known exactly what physical processes take place. When the water evaporates, a very special kind of crystallization occurs: Normally, a crystal is a regular arrangement of individual atoms. However, not only atoms, but also entire nanoparticles can arrange themselves in a regular structure—this is then referred to as a "colloidal crystal."

The silicate nanoparticles come together to form such colloidal crystals when they dry in the rock and thus jointly create new connections between the individual sand grains. This increases the strength of the sandstone.

Measurements at the large-scale research facility DESY and in Vienna

To observe this crystallization process in detail, the TU Wien research team used the DESY synchrotron facility in Hamburg. Extremely strong X-rays can be generated there, which can be used to analyze the crystallization during the drying process.

"This was very important to understand exactly what the strength of the bonds that form depends on," says Joanna Dziadkowiec (University of Oslo and TU Wien), the first author of the publication in which the research results have now been presented. "We used nanoparticles of different sizes and concentrations and studied the crystallization process with X-ray analyses." It was shown that the size of the particles is decisive for optimal increased strength.

To this end, the TU Vienna also measured the adhesive force created by the colloidal crystals. For this purpose, a special interference microscope was used, which is perfectly suited for measuring tiny forces between two surfaces.

Small particles, more force

"We were able to show: The smaller the nanoparticles, the more can they strengthen the cohesion between the sand grains," says Joanna Dziadkowiec. "If you use smaller particles, more binding sites are created in the colloidal crystal between two sand grains, and with the number of particles involved, the force with which they hold the sand grains together thus also increases."

How many particles are present in the emulsion is also important. "Depending on the particle concentration, the crystallization process proceeds slightly differently, and this has an influence on how the colloidal crystals form in detail," says Markus Valtiner. The new findings will now be used to make restoration work more durable and more targeted.

More information: Joanna Dziadkowiec et al, Cohesion Gain Induced by Nanosilica Consolidants for Monumental Stone Restoration, *Langmuir* (2022). DOI: 10.1021/acs.langmuir.2c00486

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