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Consolidation of carbonate and silicate stones: a study on combined treatments with diammonium phosphate and lime-based nanomaterials

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Porous limestones and sandstones have been widely used for the construction of monumental buildings and other stone artifacts of historical relevance. Due to their porous nature, they are subjected to atmospheric weathering, which generally leads to a loss of cohesion of the grains.
It is thus of great importance to preserve the integrity of such materials by applying consolidants which meet proper features of efficacy in reducing structural discontinuity, compatibility with the substrate, chemical stability and harmlessness towards operators and the environment.
In this study, a phosphate-based system, already proposed in recent years as an innovative consolidation method for stone materials [1], was further tested also in combination with lime-based nanomaterials (i.e. nanolime and nanocalcite).
The method is based on the application of an aqueous solution of diammonium phosphate, which is capable to react with available calcium ions present in the surrounding substrate and precipitate hydroxyapatite, a solid calcium-phosphate mineral phase that shows good binding properties and high affinity with the constituents of the stone.
The addition of a calcium-based nanomaterial, other than enhancing the consolidation action itself, provides the substrate with additional calcium ions which carry out a double function: i) they allow the application of phosphate-based methods also on calcium-poor substrates, as in the case of silicate sandstones; ii) they enhance the conversion to hydroxyapatite of possible unreacted ammonium phosphate residues, thus reducing the risk of leaving soluble salts circulating in the pore system.
The effects of these treatments have been studied on laboratory specimens of two different lithotypes, namely a porous limestone and a porous silicate sandstone, by means of a combined approach of several analytical techniques and tests.
The use of Scanning Electron Microscopy coupled with Energy Dispersive X-ray Spectroscopy allowed to study micromorphology and distribution of the consolidant inside the pore space; aesthetical compatibility was verified by colorimetric analyses; the efficacy of the treatments was confirmed by measurements of ultrasound pulse velocity; physical compatibility was verified by determination of the capillary absorption coefficient; the degree of transformation of ammonium phosphate salt into hydroxyapatite was assessed by means of Fourier-Transform Infrared Spectroscopy and Energy Dispersive X-ray Spectroscopy.
This contribution aims at discussing the methodological approach and presenting the results of this study which point out that the use of phosphate systems in combination with Ca-based nanomaterials offers a promising solution for the consolidation of microstructural defects in porous stones.

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Basic literature:
[1] Sassoni, E., S. Naidu, and G. W. Scherer (2011). "The use of hydroxyapatite as a new inorganic consolidant for damaged carbonate stones". In: Journal of Cultural Heritage 12, pp. 346–355.