Nanostructured lime-based materials for the conservation of calcareous substrates

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Nanolimes, i.e. dispersions of calcium hydroxide nanoparticles in alcohol, are introduced in the practice of conservation as a possible alternative to widely-used consolidants, like ethyl silicates, which show a limited effectiveness and compatibility with calcareous substrates.

Nanolime dispersions are characterized by a very small size of the lime particles, which should provide a proper penetration within the porous network of building materials. However, the effectiveness of nanolimes reported in literature appears controversial; sometimes a poor penetration and consolidation action is reported.

In this PhD research the behaviour of nanolime products for consolidation of calcareous substrates was investigated. Based on the developed knowledge, a methodology (including solvent modification and application protocol) for improving the consolidation effectiveness of nanolimes was proposed and validated.

First an experimental campaign was carried out in order to understand the penetration and deposition of commercial nanolimes on coarse porous calcareous substrates (Maastricht limestone). The main cause of the poor nanolime in-depth deposition in coarse substrates, was identified in the back-transport of nanoparticles towards the drying surface,

The modification of the stability of the dispersion in order to adapt it to the moisture transport properties of the substrate, was chosen as strategy to improve the in-depth deposition of the lime nanoparticles.

A conceptual model, correlating the kinetic stability of nanolime dispersions to the moisture transport behaviour of the substrate to be treated, was conceived. The kinetic stability of the dispersion was controlled by the use of solvents (water, ethanol, isopropanol, butanol) with different properties. New nanolimes were synthetized and dispersed in these solvents (using also mixtures e.g. water/ethanol). Application on coarse (Maastricht limestone) and fine porous (Migné limestone) materials as well as on lime-based mortar (bimodal pore size distribution), validated the model and confirmed that optimization of the solvent is a successful strategy for improving in-depth deposition of lime nanoparticles.

The application procedure of nanolime dispersions was also studied and optimized, being crucial for a successful consolidation in practice.

The effectiveness and compatibility of nanolimes with improved properties and a fine-tuned application protocol were verified. Results showed that nanolime dispersions can guarantee an in-depth consolidation, with only moderate alteration of the properties of the substrates.

Nanolime dispersions, if properly formulated and applied, can thus be a suitable and compatible alternative to ethyl silicates for the consolidation of coarse porous lime-based substrates.

The dissertation provided guidelines to support restorers in the choice and application of nanolime on calcareous substrates.