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Consolidation Prior to Hydrophobization – Tools of a Practical Restoration Kit*

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Abstract

Natural stones are mineral mixtures with varying qualitative and quantitative compositions as well as important differences in porosity and mechanical properties. Due to physical, chemical and biological weathering processes historical buildings and monuments often show considerable damages in and below the surface area which require various restoring measures.

During the last two decades silicic acid esters as stone-like materials have been widely used for restoration, in particular with the following goals:

(i) To restore the original stability of deteriorated sandstones (consolidation),

*. This is a compact version of this contributon. The full length paper will be published in "Int. J. Restoration and Protection of Monuments"

(ii) to reduce the water uptake of natural stones below a given limit, thus avoiding all weathering effects based on the presence of water in the porous system (hydrophobization).

The process of hydrophobization was developed first by trial and error, later on the basis of thorough macro- and microscopic investigations including elaboratesurface analytical methods like TOF-SIMS, MAS-NMR and IR spectroscopy. It is well established and in most cases leads to effective protection if the silylester application is carried out with experience and competence. This area of restoration, therefore, offers few problems for fundamental research in chemistry. On the other hand, the broad field of consolidation of damaged sandstone matrices is a real challenge for chemical exploration, due to the observation that studies of stability profiles of deteriorated natural stones have revealed some especially difficult cases which ask for a bunch of mutually supporting restoring activities. These have to correspond to special conservative demands and, at the same time, to respect the individual properties of the stone material. Our investigations in this important area of stone protection are aimed at the development of so-called elastic stone strengtheners on the basis of the traditional compound tetraethyl-ortho-silicate (TEOS).

Requirements of elastic stone strengtheners are:

- Sufficient consolidation even of highly damaged stone material including the flexible bridging of cracks.
- Restoration of the original elastic and mechanical properties of the damaged zone in order to avoid abrupt change of hardness in adjacent regions.
- Elastic consolidation without drastically enhanced hydrophobization to allow further restoration steps on the basis of aqueous substrates (for example historical plasters or slurries for pore filling).

From the viewpoint of applied chemistry the reduction of stress in the hardened stone strengthener can be achieved by two different measures:

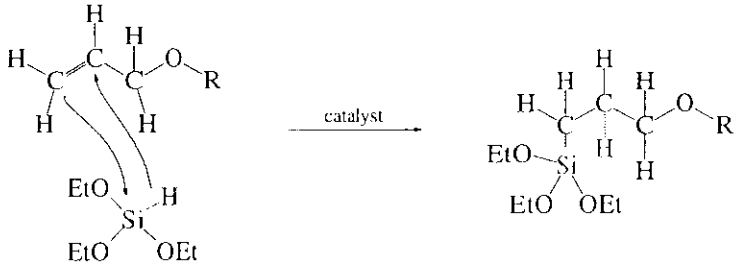
a) By lowering the degree of cross-linking in the polycondensate of TEOS via three- or two-link additives,

b) by introducing flexible chains as bridges between solidifying components which, however, may cause an undesired increase in hydrophobicity. This can be avoided by polar links within the flexibilizing segments.

In combination with the traditional stone strengthener TEOS two types of compounds are of special interest to realize elastic segments in the resulting silica gel:

- Flexible bridges with hydrolyzable Si-O-C links as in $[-SiO(CH_2)_nOSi]$ compounds,
- molecules with non-hydrolyzable Si-C bonds and polar groups in the bridging chains.

In spite of the more difficult preparation and consequently higher price, systems with stable Si-C bonds are superior to the first class of chemicals because they guarantee a higher durability of the applied binder. Therefore, our synthetic program was adjusted to the second type of compounds which can be produced at a reasonable price by catalytic hydrosilylation of olefinic groups according to eq. (1).



Allylether + Triethoxysilane $\xrightarrow{\text{catalyst}}$ (Alkoxypropyl)-triethoxysilane

By variation of the olefinic component more or less hydrophobic systems can be prepared.

In the final paper all practical aspects of the novel concept will be presented and thoroughly discussed, and first examples of applications will demonstrate the advantages of a "Restoration Kit" developed in the project "Schutz von Steinoberflächen durch Applikation elastischer Kieselsäureester" with financial support of Deutsche Bundesstiftung Umwelt.