A few notes on research and restoration works carried out at the Faculty of Restoration, University of Pardubice within the frame of the EU project STONECORE.

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ABSTRACT

This paper discusses the main activities performed at the Faculty of Restoration, University of Pardubice within the frame of the EU project STONECORE. As one of the partners of the project, the Faculty of Restoration focused on research into the consolidation of calcareous materials by means of a nanosol of calcium hydroxide. The research was aimed mainly at the optimalisation of the behaviour of nanosol-based consolidants. This was achieved through on-site application, trials to explore the possibilities and limits of consolidation, the evaluation of the strengthening effect of different agents and the selection of the optimal way to apply them on real historic monuments under real conditions.
At the beginning of the project four pilot historic monuments were chosen for testing the consolidation of their material (stone, mortar) by means of a commercial calcium hyroxide nanosol (CaLoSiL). After several months of testing and laboratory research performed in cooperation with several renowned institutions within Europe, two historic objects – the first for limestone, the second for lime mortar –- were chosen for final testing. A concept for consolidation as well as the whole restoration of each monument was devised on the basis of this previous examination and testing. Both historic objects were restored according to these concepts during the first half of 2011.

Keywords

Conservation, consolidation, nanosol, limestone, rendering

1. Introduction

The Faculty of Restoration, University of Pardubice was one of the partners of the EU project STONECORE that focused on research in the field of consolidation of calcareous materials by means of nanosols of calcium hydroxide. The task of the faculty was to cooperate in laboratory research aimed mainly at the optimaliaation of the behaviour of nanosol-based consolidants under laboratory condition and during on-site application. Based on the results obtained, final conservation treatments using nanosol-based consolidants were performed. During the project two historic monuments were chosen for this purpose – the former monastery Rosa Coeli in Dolní Kounice in South Moravia and a statue of an angel with a child from Kutná Hora in Central Bohemia. In the first case, treatment was focused on the conservation of historic lime rendering in the 2nd floor of the monastery cloister. In the second one, treatment was focused on the conservation of a whole statue made of limestone. A concept for consolidation and a concept for the whole restoration of each monument was worked out on the basis of previous examination and testing. Both historic objects were restored, according to these concepts, during the first half of 2011.

Figure 1 Former monastery Rosa Coeli, Czech Republic

2. Laboratory Research

The laboratory-based research was aimed mainly at the ability of the nanosols to penetrate and consolidate calcareous materials under different conditions. For this purpose, two sets of samples were used. The first set contained test mortars prepared in the laboratory. A second set contained real historic material collected from

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the pilot sites, i.e. samples from real historic monuments.

The behaviour of the nanosol-based consolidants in dry samples was observed. The influence of water soluble salts and humidity on its penetration was studied using scanning electron microscopy. The degree of consolidation of the samples was measured by various strength tests. Optical changes of the consolidated material were detected by means of spectrophotometry.

Special care was given to the reduction and elimination of a white haze formation that occurs occasionally on the surface of the sample after treatment.

3. On Site Investigation

The on site investigation was based on the results from the laboratory research of the test samples and the samples of original material taken from the pilot monuments. Its main goal was to test the behaviour of the nanosol in "the real world conditions". To this end the ability of the nanosol to penetrate real, historic materials under the real weather conditions was tested. The optimal way to apply the consolidant to lime mortars and limestone while preventing the formation of a white haze on its surface was also studied. The results of consolidation after different numbers of application cycles was observed on site as well as in the laboratory.

Figure 2 Former monastery Rosa Coeli, Czech Republic, testing of the consolidation effect, September 2010

As a part of the investigation of the consolidation effects of the different consolidants a number of physical parameters was measured by the Institute of Theoretical and Applied mechanics of the Academy of Sciences of the Czech Republic, v. v. i. – ARCCHIP Centre of Excellence, another of the partners in Project Stonecore.

Six commercial products intended for the consolidation of calcareous materials were tested (silicic acid esters, nanosols of $Ca(OH)_2$ in alcohol and a consolidant based on colloidal silica) on render at the cloister of the monastery, Rosa Coeli. Penetration depth, consolidation of the surface, consolidation of the mass, water absorption and visual changes were observed using the "peeling test" method, micro-drilling resistance measurement and water uptake measurement. Based on the results of the tests CaLoSiL E 25 was chosen as most appropriate agent for the structural consolidation of the mortars.

Laboratory and on site investigations led to the selection of appropriate treatments for the demonstration of the consolidation of calcareous materials by means of calcium hydroxide nanosol, CaLoSiL within the frame of a real conservation-restoration process.

4. Consolidation of Calcareous Materials by CaLoSiL as a Part of Conservation-Restoration Process

4.1 Monastery Rosa Coeli in Dolní Kounice

The historic render in the cloister of the former monastery Rosa Coeli in Dolní Kounice was chosen for final consolidation by means of CaLoSiL.

Two essential layers of lime rendering were detected during preliminary on-site investigations. The first layer, apllied on masonry made of stones and bricks, is preserved in fragments. This mortar is quite coarse and very crumbly. It contains tiny particles of carbonsed lime. Its pinkish colour is caused by iron compounds (oxides and hydrated oxides) present in the sand.

The second layer comprises a coarse, very corroded mortar of greyish colour. This render covers approx. 45% of the surface of the wall.

The state of preservation of the render in the cloister was designated as in a "state of emergency". Both renders were disintegrated, their surface was very open and very crumbly. They had lost adhesion to the masonry locally. In some areas the surface was covered with a very thin and fragile layer (pollution) under which the mortar was totally damaged. Locally, there were cracks and crevices in the mortar.

The main goal of conservation of the renders was to prevent further deterioration of the mortar and to preserve its present visual appearance. Conservation consisted mainly of the consolidation of the surface and the mass of the mortar (improving of cohesion) and the fixing of the loosened render to the masonry (improving of adhesion). Conservation was carried out during May 2011.

The surface of the render was consolidated in three cycles using CaLoSiL E 25. For the best results to be achieved it was found to be important to prevent back-migration of the consolidant which results in poor penetration and consolidation and the formation of a white haze on the surface. For this reason, application of the nanosol was performed during the early and late hours of the day. The treated areas were covered with plastic foil immediately after application to slow down the rate of evaporation of the solvent.

Cracks and crevices were filled with CaLoSiL paste which was also used for injection on the loosened mortar. Edges of the plaster were fixed with lime filler.

4.2 Statue of an Angel

A Baroque statue dating from 1764 of an angel is a part of a large composition of Madonna and Child with two angels on the sides. The original location of the statue is a wall of a private house in the city centre of Kutná Hora. The statue is made of so called "Kutná Hora limestone" which is a coarse-grained, sandy limestone with a high porosity.

The restoration treatment and its evaluation was based on a delicate conservation approach and the results from a detailed examination of the statue (visual examination, petrography, ultra-sonic transmission, stratigraphy, optical microscopy, SEM, drilling resistance measurement, water absorption and salinity measurement) and the systematic laboratory testing of the consolidation of samples of Kutná Hora limestone with nanolime-based consolidants.

The main phenomena of damage based on the results of the preliminary investigation were:

1) the vast loss of the authentic surface of the statue caused by the sulphatisation of $CaCO_3$, the destruction of $CaCO_3$ bond by $CaSO_4$ and, locally, by the formation of gypsum crusts;

2) crumbling and the considerable loss of stone mass caused by improper hard fillings in the concrete used during previous restoration treatments;

3) microbiological attack (green algae).

The task of the conservation process was to stabilize the statue through structural consolidation, grouting and the fixing of the borders of the damaged limestone parts using materials compatible with the original stone. The conservation treatment involved also the removal of dust and dirt, the reduction of gypsum crusts, the filling in of certain parts with an appropriate filler (chosen after laboratory testing), colour retouching and the placing of the statue back in its original location.

All consolidation treatments (structural consolidation, grouting, fixing) were done using nanosol-based consolidants from the CaLoSiL family.

The result of the conservation treatment of the statue will be compared with the results of the conservation treatment of the other statue of an angel from the whole sculptural composition which was performed using organosilicic acid esters in the autumn 2010.

5. Conclusion

Two historic objects in the Czech Republic underwent conservation-restoration treatment within the frame of the STONECORE project. The treatment was in both cases based on a thorough investigation under laboratory conditions of the interaction between historic calcareous materials (limestone and lime-based mortar), nanosol-based consolidants and the climatic conditions present both during and after treatment. The conservation-restoration process had to match national standards for monument care. Despite being the first example of the use of nanolime-based consolidants in such a scale in the country, the results are satisfying and show great promise for the future.

Figure 3 Statue of an Angel, before the treatment, September 2010

Figure 4 Statue of an Angel, after the treatment, April 2011