New Materials for the Protection of Cultural Heritage

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1. Introduction

Safeguarding cultural heritage is very closely connected with previous diagnostics, scientific examination and protection of the material of which the work of art has been made. Special attention must be paid also to all new materials and technologies potentially appropriated for the conservation, restoration, displaying or storage of historical monuments.

The protection of cultural monuments consists inter alia also in the parallel care of the artistic value of the works of art and of historical materials. This brings about the necessity of multidisciplinary approach to the protection of cultural heritage representing the combination and co-operation of two not entirely ”compatible” worlds - the world of humanities and the world of science.

2. Methodological Approach to the Examination of Materials

For proper assessment of the suitability of the material to be used in the protection of cultural monuments it is necessary define the elementary criteria which can be evaluated by exact methods, which provide a representative characterisation of the given material and of the conditions of its use.

Generally speaking, these criteria should include:

- The study of basic properties of the new material, in particular its chemical composition, physical and mechanical properties, service life and ageing history.
- The evaluation of interaction between the new and historical materials, which includes theoretical and particularly practical verification of the co-existence of the original and the new material.
- An assessment of the durability and the ageing after the application of the new material.
- Proposals for and verification of careful removals of the new material without damaging the original.
- And last but not least it is necessary to assess also the aesthetic acceptability of the new material.

Before deciding on the use of new materials safeguarding monuments it is very useful to answer a few basic questions:

- What is the goal of application?
- Is it possible to evaluate the efficiency of intervention?
- Is it really necessary to do the intervention or to use new material?
- What about the price?
- Is there any traditional or tested way how to do it?

This approach would have been very useful in the Czech Republic after 1989 because unpremeditated application of modern materials is very closely connected with the commercial pressure of manufactures and distributors of ”new, modern and nostrum materials. They sense a good job in the field of monument protection especially in the field of renovation of architectural heritage.

If some ”modern” materials began to be used - and, unfortunately, are still being used - without any basic research into their properties in the ”protection” of cultural monuments the damages are unmeasured.

By way of example we can mention the use of concrete in stabilisation of stone or bricks walls in 70´s, vinylacetate emulsion in the consolidation of wall paintings in or in the application of fluates to consolidation of stone surface atc.

3. Modern materials

Most ”modern” materials were developed in the course of the past 100 years and in the prevailing majority of cases they were developed for other, mostly industrial purposes and their application to monument conservation has been secondary.

They include - almost without exception - artificially synthesised organic substances - polymers - that are used in almost all fields of monument protection.

Especially protective coating systems for metallic or wood constructions or some times for arts-and-crafts objects are very successful group of new materials which are substituted traditional ones quite completely and with the great results.

4. Traditional or new?

As the properties of different materials are influenced (to a certain extent) by the technology of their manufacture as well as (and to a considerable extent by) the manner of their processing and the conditions of their exposure, it is possible to say that if some ”traditional” materials are produced at present by modern technologies and after it process by half-forgotten handicraft methods, these ”traditional” materials are becoming new materials to a certain extent and should be assessed as such

By way of example let us mention air-hardening lime. Limestone was traditionally fired in shaft kilns with wood at a temperature of about 850°C. At present it is fired generally in rotary kilns, most frequently by electric power or gas at a temperature of about 1000°C[1]. Previously it was slaked in slaking boxes where it was left to mature even for several years. At present lime is delivered mostly as dry hydrate and it is used very often without maturing.

In the recent past lime-based binders have been replaced with cement which has principally different properties from lime and, consequently, requires entirely different processing. This change has broken the handicraft continuity of lime processing and what is the result? Historical lime mortars and plasters and the present ones are two different materials because the present lime, when compared with lime prepared some centuries ago, is an entirely different, new material.

This statement, however, testifies also to the importance of the attention that should be paid to the examination of traditional but contemporary materials, which should be given preference in the care of historical monuments.

[1] 90% production of lime is used in Czech Republic for other than building purposes

5. Conclusion

Development of new materials for the safeguarding of cultural monuments and the verification of the properties of adequate materials form part of monument conservation. This part is developing slowly and with difficulties in the Czech Republic.

A comprehensive approach to the assessment of suitability of new materials for the protection of cultural heritage is highly desirable. It requires, apart from scientific contemporary approach, also knowledge of historical ways of production, construction, handicraft and arts-and-crafts processes adequate methods of diagnostics of historical materials.

Some modern new materials and technologies for the protection of cultural heritage undoubtedly possess a number of excellent and unique properties. Very often, however, they replace in modern cover the traditional ones.

So let me finish by the witticism ”Almost everything has been already invented, but a major part of it has been forgotten”.

6. Projects Solved in the Czech Republic in Recent Years

The verification of the adequacy of application of new materials to the protection of cultural monuments or the formulation and testing of new materials for the given purposes in the Czech Republic is based on interdisciplinary approach in most cases. Unfortunately, there is no institution established specifically for this purpose.

6.1 FIBRE REINFORCED MIXTURES FOR RESTORATION AND SAFEGUARDING OF MONUMENTS

In charge of the project: Miloš Drdacký

Institute of Theoretical and Applied Mechanic, Academy of Science of Czech Republic, 2000 – 2002

Research into lime based mortars with fibers is aimed at application in cultural heritage protection, especially at restoration and completion of historic objects by means of inorganic materials with pores. The project is solved by interdisciplinary team of experts by means of theoretical as well as experimental techniques. Theoretical research is based on mathematical modeling of composite materials with inorganic (brittle) matrix with different types of fibers. The mortars with fibers are expected to be resistant against micro cracks propagation as well as occurrence of macro cracks. Further advantages are expected in the improvement of physical properties, for example, permeability of material due to increase in porosity.

Properties of mortar samples with different types and varied quantity of natural as well as modern polymeric fibres are now experimentally tested. The main interest is to find out the dependence between the varied quantity of different type of fibres and mechanical as well as chemical and physical properties of samples

Mechanical behaviour (compression and bending strength and fracture toughness) are tested by method of fracture mechanics. Some physical and chemical behaviour (workability, absorption capacity, specific gravity, porosity, temperature resistance, degree of carbonization) and durability of mortars are evaluated in the Technological Department of The State Institute for the Care of Historical Monuments.

The main result is to be understanding of the role of fibers in lime mortars and scientific recommendations for compound formula and technology procedures of preparation of mixtures.

6.2 DEVELOPMENT OF PLASTER MIXTURES FOR RESTORATION OF HISTORICAL BUILDINGS AND ANALYSIS OF THEIR PROPERTIES

In charge of the project: Pavla Rovnaníková

Chemistry Department of the Faculty of Civil Engineering of the Brno University of Technology, 2002 – 2004

Research into lime based mortars and plasters is solved at the Faculty of Civil Engineering of the Brno University of Technology with the cooperation of the Chemistry Department and Department of Structural Mechanics.

The project concerns development of new binder mixtures for the safeguarding of historical buildings. The composition of these mixtures has to be as close as possible to the original historical binders and at the same time it must possess the properties for the formation of stable and durable solid structure, with advantageous mechanical and physical properties.

The new mixtures will be based on quicklime and pozzuolana or hydraulic admixtures available in the Czech Republic.

Chemical reactions of binders during the formation of the final solid structure will be tested under different temperatures and moisture conditions. The formation of micro-cracks under mechanical load will be investigated by a method of fracture mechanics to clear up the reasons of the formation and distribution of cracks, which are both technical and aesthetic defects of plasters. The final products will be studied from the point of view of heat, vapour and transport of water salt solutions. Computer simulation will test the service life of new mixtures.

The project will make clear the basic empirically known phenomena of materials and technology that were used in the past. On the basis of the results achieved it will be possible to select proper materials for exterior plasters for historical buildings and avoid defects due to the use of inappropriate binders.

6.3 HISTORICAL CONSTRUCTIONS AND MATERIALS UNDER CYCLIC LOADING

In charge of the project: Miloš Drdacký

Institute of Theoretical and Applied Mechanic, Academy of Science of Czech Republic, 1997 - 2000

Part of this project focused on the different consolidating materials for the conservation of stone was realised in the Technological Department of State Institute for Heritage Preservation. This research aimed at the impact of conservation coatings on the different types of sandstone and limestone, mostly used for monuments in our country.

Stone samples were treated by the selected historical as well as modern conservation agents - line oil, lime water, fluates and polyacryl emulsions, polyacryl solutions and solutions of fluoropolymers and polysiloxanes.

Effects of conservation treatment were evaluated immediately after treatment and after artificial ageing. The physical and mechanical properties of stones and theirs changes were measured (resistance to salts, frost resistance, vapour permeability, dynamic and bending strength). The changes of the surface were studied and documented by means of SEM (scanning electron microscopy).

Individual results were published piece meal (1999 - 2000) in ZPP (Zprávy památkové péče) and as an integral whole at the International Congress on the Deterioration and the Conservation of Stone in Venice (2000).

The results are very useful for the choice of the best consolidant for a certain type of stone or for evaluating the deterioration of historical stone caused by wrong conservation treatment in the past.

6.4 NEW LIME BASED MORTARS FOR CONSOLIDATION OF HISTORICAL PLASTERS ESPECIALLY UNDER WALL PAINTINGS

In charge of the project: Ivana Kopecká

State Institute for the Care of Historical Monuments, 1996 - 1997

The project was solved in the Technological Department of The State Institute for Heritage Preservation in and in the co-operation with specialists from The Institute of Chemical Technology in Prague.

The aim of this project was to explain how to modify workability, the physical and mechanical properties of lime based mortar by means of very low quantities of organic additives.

The solution was motivated by the fact that even the ancient builders modified the qualities of lime-based mortar by organic substances. In the work we tried to re-discover half-forgotten experience by using similar but modern substances (redispersible polymers dispersion, water retarders and water reducers).

On the basis of acquired knowledge and experience suitable lime-based conservation mortars with precisely defined qualities were developed.

The results of this project are published in Historic Mortars: characteristics and tests, RILEM, 1999, by D. Michoinová.

New consolidating lime-based mixtures have an extremely wide range of use in the consolidation of historical lime mortar, for instance, for injecting delaminations, for the consolidation of the back sides of transferred parts, for affixing the transferred parts of wall paintings and for filling ruptures and cracks in plaster.

Consolidating lime based mixtures, with the trade mark Terrako is now available for restorers in three modifications.

6.5 POLYMER SORBENTS FOR THE MODIFICATION OF INDOOR ATMOSPHERES OF MUSEUMS AND STORE-ROOMS

In charge of the project: Martin Dvořák

State Institute for the Care of Historical Monuments, 1996 – 1999

The preparation and testing of polymer sorbents with an ability to control humidity, to absorb pollutants and possibly also with bacteriostatic effect, was the aim of the project which was solved in cooperation with the Institute of Macromolecular Chemistry of the Academy of Science of the Czech Republic and the National Museum.

The degradation of objects of cultural and historical value exposed or stored indoor is caused particularly by the influence of aggressive environment. The variables most influencing the process of deterioration are temperature and humidity, acidic pollutants (SOx, NOx, fumes of organic acids, etc.) and also biological factors (bacterias, moulds, etc.) and it was expected that some polymer sorbents with optimal properties can keep these variables within expected limits in the microclimate surroundingv the exhibited or stored works of art. The sorption properties of 20 sorbents with different matrix and functional groups were tested. The glycidylmethacrylate- co - ethylene dimetacrylate (GMA - EDMA) gave the best results from laboratory testing but testing in real museum conditions (Naprstek Museum in Prague and storage dept. in Liběchov) does not confirm expected sorption properties inside the showcases.

6.6 TECHNOLOGICAL RESEARCH IN MEDIEVAL WALL PAINTINGS IN BOHEMIA AND MORAVIA AND STUDY OF THEIR CONSOLIDANTS FOR CENTRAL EUROPE CLIMATE

In charge of the project: ing. Ivana Kopecká

State Institute for the Care of Historical Monuments, 1996 - 1997

The aim of the project was relationship between the technique of wall paintings and the materials used for these techniques. Attention was paid especially to the analyses of organic binding media because in Bohemia and Moravia “secco” was the technology used only for wall painting. The results showed that the egg was the binding medium most common in Bohemia and the gums of polysacharides were often used in the south of Moravia.

In the second part of the project the consolidants for mortars especially under wall paintings were compared in the depth of penetration of consolidants and the vapour permeability of the mortar before and after treatment. Five different consolidating agents were tested (two types of acrylic emulsions, acrylic solution, polysiloxanes and solution of propylcellulose derivative). The changes of mortar surface after treatment and after artificial ageing were documented by the scanning electron microscopy. The loss of consistence and loss of weight after artificial ageing of mortars treated by different consolidants were evaluated.

The best results were registered after treatment by acrylic solution and by polysiloxanes. The results after treatment by acrylic emulsions and solution of propylcellulose derivative were very poor. The results of the project were published in ZPP (1997) and are used as didactic material for post-grad education of people working in heritage preservations.

6.7 TECHNOLOGIES FOR CONSERVATION OF COPPER ALLOYS MONUMENTS

EUREKA EU 360 COPAL

In charge of the Czech part of project: Dagmar Knotková a Kateřina Kreislová

SVÚOM Ltd. , 1994 - 1999

The patina layer not only completes the aesthetic value of the object but it is also important for a long-term behaviour of the work of art in the surrounding environment. The natural green patina with steady properties is formed in atmospheric conditions in 10 – 20 years according to the corrosivity of the atmosphere. The corrosion products layer is subjected to transformations during the formation period – the first 5 years of exposure.

The requirement of forming the artificial patina is evoked by the need to receive homogenous green layer in a short time or to receive a layer with specific aesthetic properties. There are many procedures to achieve this, handicraft or operational, including continual processes. The artificial patina cannot be identical with steady-state natural patina. It is necessary to understand these layers of chemical patina as a temporary measure or to protect artificial patina layers by coating paints or wax products. The maintenance or renovation of these protective layers without aesthetic changes of the work of art is difficult.

Stability and transformation of artificial green patina layers were studied by testing at atmospheric corrosion test sites and by evaluation on monuments under restoration. Sheets with industrially produced layers of patina (Nordic Green, Tecu-Patina) were tested too. The results of visual inspection, X-ray diffraction analyses and digital analyses of pictures were presented to demonstrate the effects due to exposure at open air up to five years of exposure. Artificial patina Nordic Green was used on copper roof of the Belveder Summer Palace in Prague.