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METHODS OF PROTECTION OF NATIONAL ARCHITECTURE MONUMENTS

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ABSTRACT

The paper discusses the problem of monuments conservation in terms of technical implementation and based on the importance of conservation of historical content, and it helps to skillfully handle the complicated untypical tasks on all surfaces, be it facade repair, building waterproof, or wood protection.

Also, we studied the causes of weathering and fracture of facade construction materials of old buildings. In the restoration process, we suggest using materials from sacrificial, sanitizing and compression plasters and the correct application of desalination compresses, which is a reliable, effective method of salts removal. In addition to special sand-blasting and chemical cleaning of dirt, interior walls may be cleaned using a removable latex film for eliminating contaminants.

KEYWORDS: restoration, monuments, desalination, conservation, stone-strengthener

1. Introduction

Restoration of buildings and constructions is an extremely difficult type of work that requires the joint work of various specialists, and especially restoration architects, engineers and construction technicians.

The purpose of measures of monuments protection is their long-term conservation. Cultural heritage is extremely important to society, especially for the possibility to know our own history on the example of real historical evidence. This statement is true for small regions in particular, and for Europe as a whole. Heritage Preservation is a component of the quality of life. We consider the complex problem of monument preservation not only in terms of technical implementation, but also from the point of view of historical content conservation, helping to skillfully handle complex atypical tasks on all surfaces be it facade repair, building waterproofing, or wood protection.

The slightest mistake can lead to loss of irreplaceable cultural heritage. With the constant improvement of technology and searching opportunities for conservation of our cultural heritage, we have carefully and conscientiously select concepts and draw up recommendations for the use of products. This includes understanding and recognition of coexisting, and sometimes almost opposite concepts in the restoration of monuments: restoration using a new material, or preservation and strengthening of the initial state.

2. Case study

The restoration of an important architectural monument cannot in any way be compared with the construction of new buildings from ground. When constructing new facilities there are opportunities for an extensive reorientation and technical improvements, while during reconstruction activities, and even more so for conservation, we must start from the existing state of the structure. From here follow a number of special factors that must be considered to ensure that restoration activities are successful. A careful examination and analysis of the situation, the examination carried out on site, as well as laboratory tests of material samples, are an integral part of activities planned for reconstruction (Fig. 1).

Studies conducted by us as on a construction site and in our laboratories allow us to find cost-effective materials and methods of their application, ideally meeting the goals set for restoration or construction.

Based on these studies, specific recommendations are given with the name of the material, its processing method and timing of works.

These carefully crafted recommendations provide guidance to the contractor industry. Not only the technical features, but also historical, architectural and restoration details are taken into account, as it is necessary to preserve facade appearance with minimal intervention. For this purpose, in most cases a thorough examination of the structure is a must; further monitoring of work performance is advised.

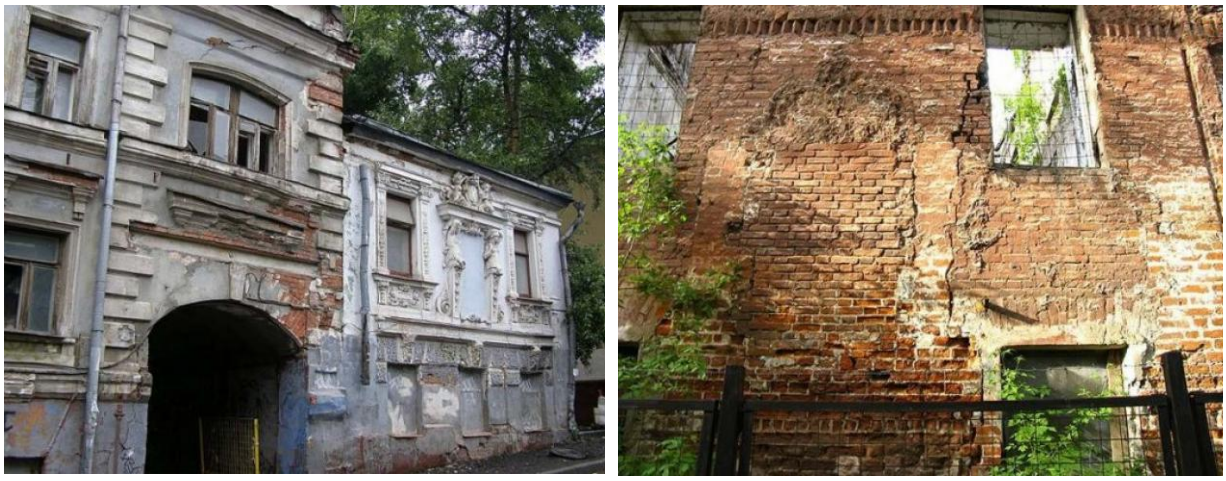

Fig. 1. *Exterior of historic buildings 17th-19th centuries in Chisinau*

3. Methodology and results of a complex study

3.1. Causes of weathering and destruction of building materials

Every professional in construction knows the white beards, as if growing from the damp masonry in older buildings. They can lead to plaster peeling or even to stone breakaway. Non-professionals often refer to these salt layers as wall nitrate - a concept that barely meets the actual state of things.

The salts are not only a necessary component of life on earth, but also a component of many building materials based on minerals. Salt solubility plays an important role in the process destroying the clutch, and there is a close connection between salt and humidity. Ingress of water and dissolved salts in the pores of building materials is in most cases the root cause of weathering.

The penetration of water often causes a range of complex physical and chemical processes which in turn can lead to erosion.

Without the presence of excess moisture in the material, damage caused by frost, as well as chemical and biological corrosion, would not have such frightening proportions. Salts dissolved in water affect the construction masonry of porous materials and in the case of mechanical and chemical stress, can lead to destruction.

The penetration paths of moisture in the construction masonry are varied. Water can rise through capillaries, penetrate into the masonry under pressure as leaking moisture or with the rain through open pores, cracks and construction joints.

The water in the gaseous state can penetrate into the masonry as the result of hygroscopic water absorption and capillary condensation.

It is not possible to draw a clear boundary between physical and chemical corrosion. A typical chemical process is, for example, the loss of a binder component of the building material because of its transformation into a soluble salt (solvent corrosion). The process of crystallization of salts formed at the same time is often associated with an increase in their volume, and this process is characterized as a physical one.

Typical types of physical weathering are:
- the crystallization of salts;
- the hydration salts;
- freezing and thawing;
- hygroscopic expansion/shrinkage.

Biological corrosion, i.e. the damage of masonry by organisms such as algae, lichen, moss and bacteria, can cause chemical damage due to corrosive metabolic products (e.g. chemicals), and the green cover formed on the clutch works as a moisture collector and prevents the normal drying of building materials.

In fact, the list of destructive processes associated with salt and humidity is much larger than the excerpt presented on these pages.

3.2. The process of desalination and purification

Compress for desalting. For a durable and successful protection of the buildings affected by salts, a complex of measures should be performed not only to block the incoming water, but also to remove the existing salts.

In addition to mechanical and chemical methods of fighting salts, which due to their destructive effect are not allowed in restoration, there is a proven physical method of extraction of salts with a desalting compress. Desalination refers to a clear reduction of destructive salts contained in porous building materials. Used in the restoration of sacrificial, sanitizing and compression plasters, the correct application of demineralization compresses is a reliable method of removing salts, proved to be effective.

Due to compress application on the masonry, the area capable to evaporate the water located in the clutch, shifts. Salts dissolved in water, have the ability to move from a building material in the pack so that the crystallization of salts occurred in the new evaporation zone outside the architectural element. At the same time compresses are not a decorative element and are not used to further protection of the masonry. Compresses are used temporarily, without causing damage to masonry, and can be reversible in nature.

Careful cleaning of the foundation. It is widely believed that the crust of dirt, which is formed on the surface of building material, can be used as a protective layer. As a rule, this statement is incorrect.

In contrast, the crust of dirt has a large internal surface, and is an excellent absorbent material for moisture and airborne gaseous and particulate (dust) emissions. These substances react inside the crust of mud and accelerate the process of destruction, even if their effect is not noticeable at first.

For dirt removal, there are several technical and aesthetic justifications:

- removal of risk factors related to the accumulation of salts and deceleration of drying;
- preparation of the foundation for further preservation activities because of recovery of capillary water absorption;
- removal of unsightly external contamination.

In addition to a special sand-blasting and chemical cleaning of dirt, the cleaning of the interior building walls may be performed using the method of removable latex film.

None of the currently used methods for dirt removal is optimal for internal cleaning. Regular cleaning requires too much water or too much dust is produced. A suitable method could be the laser treatment, but its application on large surfaces is not justified in economic terms.

Products based on special latex dispersion fill this gap. They contain a small amount of water, which quickly evaporates when applied to the wall.

Material polymerizes into a sticky elastic film with active components on the surface intended for cleaning. After hardening of the film, it is removed together with the dirt.

3.3. Preservation of natural stone

Blocking natural stone expansion. Very many natural rocks contain clay minerals which can expand. In most cases, these are layered silicates, which in structure resemble a book.

Due to the electrochemical "magnetic" property in the presence of sufficient moisture, they can retain and set free the moisture between the "pages of the book," i.e. in the intermediate layers.

The layers of minerals saturated with moisture come loose like an accordion (Fig. 2).

If the amount of moisture decreases, the fibers come together again, creating tension in the masonry structure. These destructive processes are called hygroscopic expansion or shrinkage. The action of a unique product against expansion is based on the "turning off" of clay minerals. After treatment with protective material, the positively charged metal cations, found in the intermediate layers and responsible for the expansion, are replaced with the active ingredient of the protective material. As a result, there is a significant reduction in the hygroscopic expansion while maintaining the other characteristics of the material. Subsequent treatment of the surface water repellents enhances the action of the anti-expansion product.

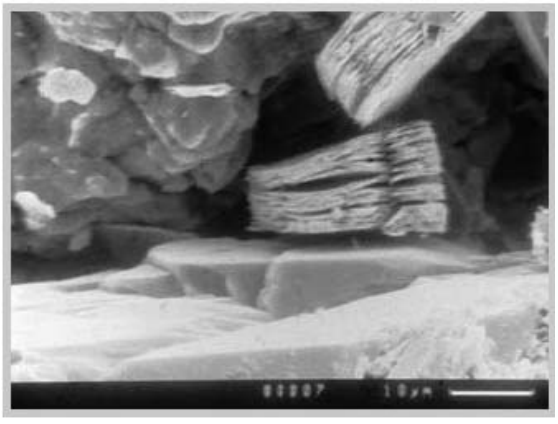

Fig. 2. *Microstructure of clay material predisposed to expansion*

Stone hardening on the basis of "classical" stone-hardeners.

Stone-hardeners on the basis of silicic acid ester ($Si(OR)_4$) by reaction with water, form reinforcing silicagel (SiO_2 aq):

$$Si(OR)_4 + H_2O \rightarrow SiO_2 \text{ aq} + 4 \text{ ROH}$$

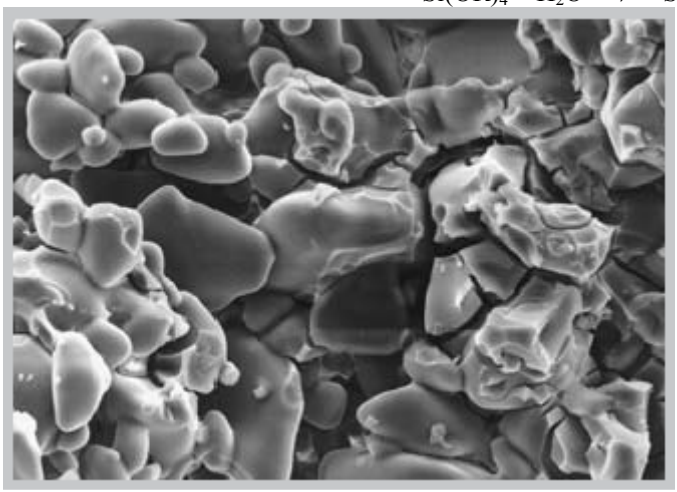

***Fig. 3**. Silica in rock pores at 300-fold increase with the electron microscope*

The active substance - silicic acid ester (Fig. 3) being a liquid, solvent addition during processing is not necessary. The ability to prepare various proportions of the mixed molecules of the active ingredient allows the variation of strengthener properties, especially in the amount of formed gel. That is, the amount of the gel, resulting in the reaction of the active substance within the pore space. Further variations in the depth of impregnation and reaction rates are achieved by varying the type and amount of added catalyst and solvents.

Through targeted experiments combining these options, a wide range of these stone hardeners was obtained. Thus, it is possible to select an individual product that is suitable for hardening any foundation (Fig. 4).

***Fig. 4.** Process of restoration of facades and column capitols*

All the classic hardeners based on silicic acid ester have one characteristic feature: silica gel is obtained from the fluid and does not form a dense structure, i.e. it creates a secondary porosity within the treated capillaries. This porosity ensures the porosity of the capillary conductivity and conductivity of water vapor in the reinforced material.

Stone strengthening using elastic hardeners.

A very small amount of gel particles of "classical" stone strengtheners reduces the area of its application on foundations with normal pores diameters. Usual hardeners are only in part suitable to strengthen the building materials with an initially large pores or with pores that increased as a result of weathering, the, and only in certain conditions.

These problematic materials include tuff, a variety of plasters, capable of expansion natural stone, cane-fiber sandstone. The reasons may be the original distribution of pore radii of natural stone, or microcracks formed due to weathering, for example,

in the case of expansion able natural stone such as cane-fiber sandstone.

Plasticized stone hardeners.

Hence the need to strengthen the previously mentioned foundations with advanced stone hardeners. In the 90's were designed silicic acid esters, meeting these requirements were designed.

With the introduction of plasticizing particles, the resulting silica becomes more elastic. The internal stresses arising from the reactions are reduced and silica gel bridges are formed (Fig. 5). Due to the release of this product group, it became possible to strengthen the very porous by nature or heavily damaged structures.

A positive side effect of these materials in comparison with classical hardeners is the improvement of characteristics of the treated material regarding expansion and shrinkage.

Through processing, the elastic modulus increases faster than the rate of strength.

a) *b)* *c)*

Fig. 5. *Stone strengthening on the basis of plasticized stone hardener: a) separation of the gel plates in about 10 μm; b) the picture registers the type and regularity of the separation of gel plates of about 10 μm; c) visible explicit linking of the gel structure in the pore space. 900-fold magnification, soft fritted saturated glass*

The purpose for the restoration of stone material is in most cases not only to strengthen the stone structure, but to improve of many other indicators, depending on the type and intensity of weathering.

Based on the similarity of silicic acid ester with most types of natural stone, as well as due to the fact that masonry is often composed of layers of different materials, the desire to solve all problems with one product is quite understandable. Stone hardeners on the basis of silicic acid ester used in silica foundations, set in motion two interrelated mechanisms. First, the ester of silicic acid is attached in a chemical reaction to the quartz substrate, and, secondly, it forms in the pore space of the foundation a three-dimensional silicate structure, which, without direct connection leads to the stabilization of the material. On calcite foundations only the second mechanism takes place. To achieve the chemical addition of silicic acid ester to the calcite foundation specially developed for this purpose, adhesion promoters are used. These substances interact with covalent compounds of quartz and polar compounds of limestone, and involve the two above-mentioned mechanisms.

3.4. Innovative processes for in-depth strengthening

Strengthening during the process of vacuum circulation (VKF)

The VKF method is based on the use of back pressure technology during which the monuments, statues and facade parts are packed in a tight film, resistant to solvents (Fig. 6). If only a portion of the facade is subjected to the process, the places of contact of the film with the rock are isolated with sealing material and batten bars made of solid wood. Then, a powerful vacuum pump removes the air trapped in the film bag and pore space, while the figure itself turns into a vacuum pot. Upon reaching the desired index of relative vacuum (200-900 mbar), a specially designed reinforcing material is added, which is evenly and deeply absorbed into the stone.

Areas with open pores and the most damaged areas in the stone are filled in the first place, more dense structures - a little slower. The excess of restorative material is returned to the installation where it is again included in the cycle.

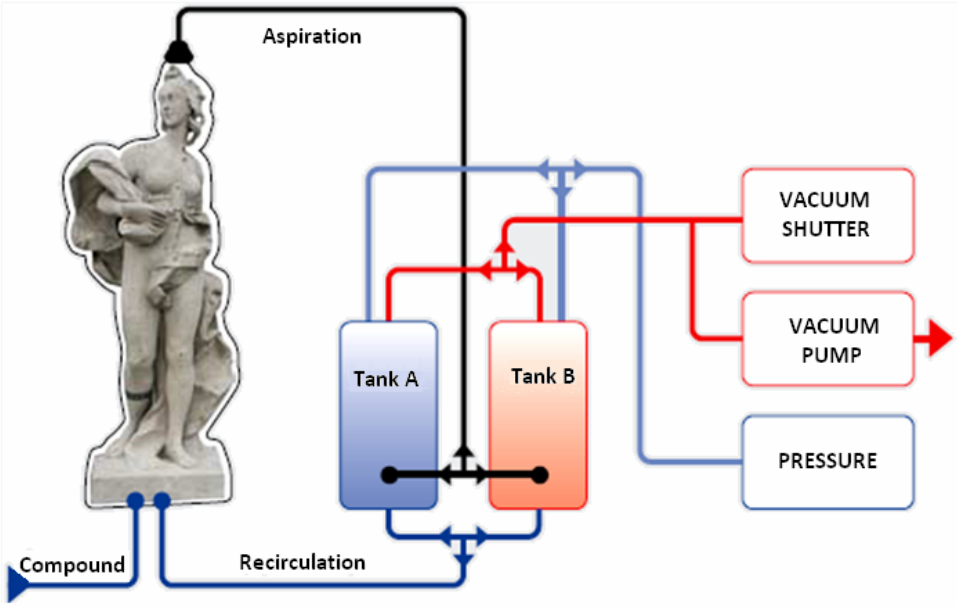

Fig. 6. *Surface hardening during the process of vacuum circulation (VKF)*

Advantages of the method:

- the pore space is completely filled with protecting material;
- the damaged material is homogenized with the intact material;
- a complete impregnation can be carried out on the site;
- the process can be repeated as many times as it's needed;
- the porous stone structure is saved, compatible with the raw material of stone;
- the intervals between subsequent restorations significantly increases.

3.5. The current process to enhance the load bearing capacity of vaults

Vaults impregnation

At the turn of the 19th and 20th centuries, vaults of many churches in the Republic of Moldova were constructed using mostly "porous limestone." After one century, many of these constructions have very severe damage and loss of hardness. In addition, the vaults often show significant changes in surface appearance, in the form of salt efflorescence, dirt, shedding up to the formation of mud cake.

This damage reduces the strength of the material and causes the loss of the original relief pattern. In some cases the size of the arch cross-section is greatly reduced, which may lead to loss of bearing capacity of the foundation, up to the danger of building collapse.

Often, historic vaults of buildings are demolished for these reasons and then reconstructed. Now it is not necessary to do that.

On the basis of experimental research a method for strengthening vaults was developed, based on the impregnation of masonry arches with a special compound (Figure 7).

This method is used in conjunction with a system of special supporting plasters and thermal insulation, laid above the masonry arch.

Masonry joints take on certain functions in the structure and therefore must meet all necessary requirements and have certain properties. This applies not only to external, but also physical, mechanical and, above all, moisture characteristics. Thus, we have a wide range of mortars to fill the joints with different types of binding elements. The mortars are separated by areas of application, as well as within each group by color, grain size and strength.

As before, the application of plaster is an important part in the modern decoration of facades. As the surface layer, besides aesthetic purposes, they originally had the function of protecting the structure from environment effects. In the restoration of historic buildings, in most cases, this is not the only technical problem. Often, much more important is the problem of internal damage by salts or moisture coming from the foundation. Only in a few "lucky" cases a simple plaster can be used, often a special recipe has to be used for selected historic plasters. It is often necessary to respond to a specific situation, using special, modern products. Depending on the situation, it may be necessary:

- to ensure dry and free of efflorescence surfaces;
- to protect the adjacent historical surface, such as wall paintings.

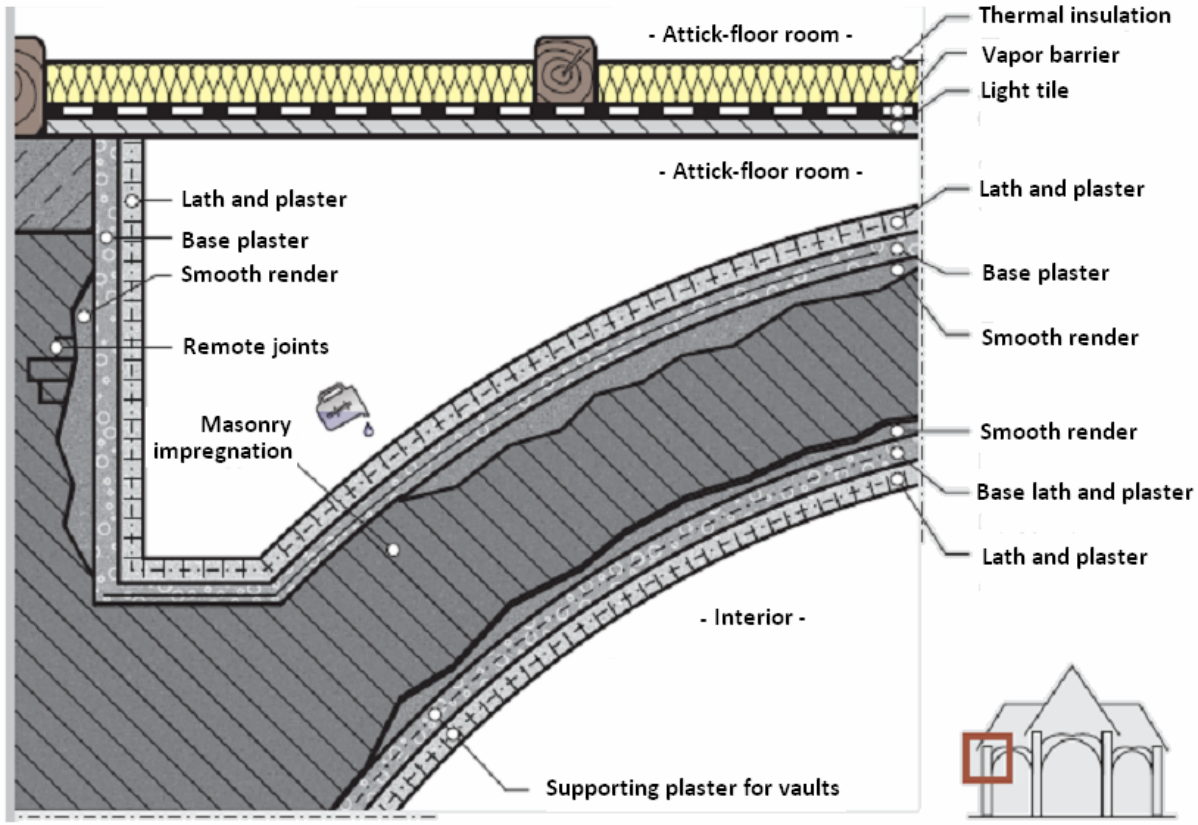

Fig. 7. *Enhancement of load bearing capacity of vaults*

Aim of restoration	Foundation	Features of mortars
Material suitable to the historical foundation	Mostly dry and salt-free	Capillary active with medium pore size
Dry and free of efflorescence freshly plastered surface for the most part without a direct connection to the original historic surface	Affected by moisture and harmful salts	Water repellent with a high pore volume in conjunction with a capillary-active plaster base
Freshly plastered surface in most cases with a direct link to the original historic surface	Affected by moisture and harmful salts	Capillary active with high pore size

Signifying plasters have in most cases, two important functions:

1. moving the evaporation boundaries of the moisture contained in the masonry into the plaster layer,

2. the accumulation of salts in the masonry without destroying the structure during crystallization.

The first problem is solved by the water-repellent, and at the same time open to water vapor diffusion properties of the plaster. The moisture that occurred in the masonry is forced into the initial layer of 1.5 to 3cm thickness to move to gaseous state, and further move to the surface as water vapors. Thus, in accordance with the second task, crystallized salt are stored in the pore space of the plaster and in the plaster under it.

4. Conclusion

Designing the protection of architectural monuments structures from moisture, weathering and destruction requires an individual approach. In all cases, one should apply a gentle but reliable solution taking into account alterations to the building structure during operation. Design requires justified use of historical and contemporary efficient materials, including concrete, if necessary.

In addition to a special sand-blasting and chemical cleaning of dirt, cleaning the interior walls

and facades of buildings may be performed using a removable latex film to eliminate contaminants.

On the basis of experimental research a method for strengthening the vaults was developed, based on the impregnation of masonry arches with a special compound. This method is used in conjunction with special support plasters and thermal insulation, laid above the masonry arch.

An integrated approach to the protection of architectural monuments structures from the negative impact of water and other negative factors, properly used, will allow reassuring them for years.

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