New Materials for Conservation of Stone Monuments in Latvia

Inese Sidraba

Centre for Conservation and Restoration of Stone Materials, Institute of Silicate Materials, Riga Technical University, Azenes 14/24, LV-1048, Riga, Latvia, e-mail: inese@ktf.rtu.lv

1. INTRODUCTION

Significant part of Latvia's Cultural heritage is the stone Monuments, buildings, decorative stone portals and carvings preserved till nowadays in the comparatively better or worth condition. For the great part of the Monuments the local stone materials, such as dolomitic sandstone, calc-tufa and dolomite were used. For some objects the materials from other countries were imported, e.g. calcareous sandstone from Gotland (Sweden), quartz sandstone from Obernkirchen (Germany), dolomite from Sarema (Estonia), granite from Finland, travertine from Tivoli (Italy). Among the most significant stone Monuments in Riga, capital city of Latvia, the Riga Dome Cathedral (1211), decorative portals of the Old Riga (17^{th} - 18^{th} century), Freedom Monument (1935), Ensemble of Riga Brethren's Cemetery (1936) should be mentioned.

Due to the corrosion of the stone materials, the further preservation of the stone Monuments is endangered. The deterioration of stone materials is a complex process caused by the interaction between numerous correlated factors: climatic region, urban pollution and properties of the material, leading to the chemical, physical/mechanical and biological weathering [1]. In the case of the certain object the behaviour of the construction materials under weathering conditions is also predicted by the object's design, constructive elements and adjacent materials used, such cases as use of inappropriate jointing material, iron and copper elements [2]. Unfortunately in Latvia there are quite common two extra factors to be included: the most of the problems appeared to be related directly to the apparent lack of maintenance of the Monuments and the inappropriate restoration works carried out. These factors are determined by the economical situation and lack of the knowledge and experience in the conservation of the stone materials and Monuments of Cultural significance.

In Latvia the first research of the stone conservation problems and subsequent restoration practice was started in the 80-ties of the 20^{th} century guided by the necessity of the safeguarding of stone Monuments by the mean of the previous scientific research, respect to the conservation principles and ethics. Nowadays the various specialists: chemists, biologists, geologists, physics from Riga Technical University, University of Latvia, Latvian Academy of Sciences are working on the problems of the corrosion of the stone materials in order to elaborate the scientific base for the conservation and preservation of the stone Cultural heritage in Latvia.

The use of the new materials for the conservation/restoration of stone materials in the objects of Cultural significance is not the common practice in Latvia due to the lack of the experience, scientific research facilities and limited information about the recent developments and achievements in the international conservation practice. The choice of the modern materials is mostly determined by the complexity and badly weathered condition of Latvia's Monuments and necessity of the further preservation and maintenance.

2. Essential of the work

The current work is aimed to discuss the problems and solutions of the use of new materials in conservation practice of the restoration of Freedom Monument (built in 1935). The restoration of Freedom Monument was carried out from 1998 till 2001 and was one of the most complicated and extended recent stone conservation works in Latvia.

The main items discussed are following:

A. Water repellent treatment of travertine
   - evaluation in laboratory of the silicone based water repellent products;
   - evaluation *in situ* of the performance of the water repellent.

B. New materials for the jointing of granite
   - use of the binary mixed polyurethane mastic;
   - evaluation *in situ* of the performance of the polyurethane mastic;
   - evaluation of the failure of the use of the epoxy based material.

3. BACKGROUD

3.1 Conservation philosophy.

The safeguarding of the Cultural heritage and the use of the conservation materials both traditional and new as a direct tool to achieve the stated aim are determined by the conservation principles and ethic described in the international Charters, Conventions and Recommendations issued by UNESCO, ICOMOS, Council of Europe.

The aim of the conservation is to protect the Cultural significance of the given object by maintaining the fabric of which the object is made. In practice it means to find a way of conserving the physical form of the material, which does the least damage to its qualities under protection. Therefore any work on an object must be preceded by the studies of the physical and documentary evidences, object's condition and significance of its cultural value. The evidence of the cultural values comes from the comparative quality mixture of different factors over an object's entire existence: the evolution of its construction, aesthetic, it's use and associations, context and the present condition of the all these factors. Based on the research and survey, the value of the site should be defined, and a philosophy to guide all interventions should be established.

The basic principles have to be followed in conservation are [3]:

- any intervention should be only the minimum necessary for the site's survival;
- only a minimum loss of the existing fabric is acceptable;
- any intervention should, as far as possible, be reversible;
- new work should be clearly differentiated from the old.

The following statements determine the choice of materials and techniques for the restoration [3]:

- materials and techniques should respect traditional practice;
- the use of the modern substitutes is appropriate only when:
  a. they provide a significant advantage which can be identified;
  b. their use has a firm scientific basis;
  c. their use has been supported by a body of experience.
- the new material is compatible with the expression, appearance, texture and form of the original;
- the new material meets the requirements of both the local physical and geographical conditions and the way of life of the population.

3.2 Conservation by surface treatment

The objective in applying surface treatment is to enhance durability of the stone material and the object as a whole. The water repellent treatment aims to eliminate or reduce capillary absorption of water in driving rain, prevent wet absorption of reactive gases, reduce damage effects from frost, diminish biological growth and the amount of particulate fixation preventing the soiling [4].

When choosing to apply surface treatment the side-effects and long-term effects should be considered, as well as the reversibility of the treatment. The silane based products proven to show good hydrophobic properties, but no safe methods have yet been devised to remove silane treatments once they have polymerized. The conservator should consider that the treatment is irreversible and there is possibility to cause irreparable damage to material in the long-term period.

For the treatment of the inhomogeneous porous stone materials like travertine, the risk of open porous system and cracks in a material should be considered. The water repellent normally works well if there are no cracks (ca >0.3 mm) or other defects in the material, which may allow water to penetrate, resulting in significant moisture [5]. The surface treatment is of great significance to moisture balance, having regard to the cause of dampness and the water repellent treatment alone cannot solve a major damp penetration problem. Also the possible rejection or poor penetration of protective into biofilm-coated stone surfaces has to be taken into account. Otherwise the effect of conservation measures might be of a very short-term nature or will even lead to an increase in the microbial contamination and consequently the bio deterioration activity [6]. Therefore the complex restoration and conservation process should be carried out in order to prevent the reactive components in the structure; the absence of moisture pathways from the ground or the interior; the absence of soluble and hygroscopic salts; a joint network without fissures or defects [7].

3.3 Jointing material.

Great care is necessary in the specification and execution of original jointing from the point of view of material, the impact of the style of pointing on the whole object, the impact on the construction’s durability. The pointing material is as much a part of the Cultural value of the building as the building stone and other materials. In the case, when the repointing has to be carried out in local places or for a whole building, the aim should be to match the original pointing as closely as possible. Above all, the aware of the damage that can be done to stone material in the removal of old pointing should be considered.

Using the new materials for jointing - binary mixed epoxy based materials, it is essential to evaluate the compatibility of the physical/mechanical properties (density, linear thermal expansion) of the jointing and surrounding material, the volume of the material placed in the joints, the size of the joint to be filled and the ambient temperature in order to prevent the stresses between the resin and surrounding structure [2]. Moreover it is of great importance to comply strictly with the manufacturer’s recommendation for the correct proportioning of the constituents, adequate preparation of surfaces and proper application of the material in order to achieve the required chemical bound and optimum strength.

3.4 Maintenance of the cultural heritage objects

The regular maintenance of the Cultural heritage objects, both recently restored and non-restored, is of great significance in the preservation and enhance of object’s durability. The sensible and thoughtful care can preserve the object without many mistakes and damages caused by the mean of the use of the advanced technologies. The regular survey and assessment of the objects should be considered as the one of the most important activities for safeguarding the Cultural heritage.

However even in the case if the best possible maintenance procedures are being regularly carried out, deterioration of the exposed building materials, including the newly used conservatives, will still inevitably occur due to the natural corrosive factors such as rain, wind, freezing/thawing cycles and man-made interventions such as increasing air pollution. Therefore the use of the conservative materials and intervention into object should be considered only as minimum necessary for the object's survival and not as an action for the providing long-term self-maintenance of the object.

4. Characterisation of the FREEDOM MONUMENT

4.1 Cultural significance

Freedom Monument (sculptor K. Zale, architect E. Stalbergs) was constructed in 1935 (see figure 1). The Cultural significance of the Monument is determined by its:

1. *Historical value.* The construction of the Monument and its withstand over the time represent the relevant episodes and periods in the history of Latvia.
2. *Architectural/artistic value.* Monument is the masterpiece of the famous Latvian sculptor K. Zale. The artistic idea of the Monument is expressed in the architectural, sculptural forms by the synthesis of various materials.
3. *Authenticy.* Monument is authentic in the construction materials (stone, metal, concrete), technical constructions and engineering solutions, environmental location.
4. *Socially/politically value.* Monument represents the traditions and history of the Latvian crafts of stone-works. The Monument, built by the voluntary donations, all the times had the significant role in the live of society and political activities.
5. *Emotional value.* Monument represents the symbol of national identity, independence, love of native land and continuality of these values.

Figure 1. Freedom Monument.

4.2 Construction and materials

Monument stands 40 m high from its foundation and is constructed around a concrete support structure. For the external cladding the grey and red Finnish granite and Italian (Tivoli) travertine were used. The granite stonework was originally lead-sealed at the joints;

the travertine stonework joints were originally filled with lime mortar. The obelisk is travertine encased with bronze fixings with no gap between the stone and concrete. At the top of the obelisk the copper statue of Liberty is fixed.

Stone materials. Roman travertine *Classical Light* is micro-crystalline calcite with cavernous texture, light in colour, with different types of textures and vein. Its physical/mechanical properties: total porosity 4 - 7%; water absorption about 2%; compressive strength – 111,3 MPa. Red granite *Balmoral Red* and grey granite *Nystad* have dense, homogenous texture. The physical/mechanical properties of granite: total porosity >1%; water absorption about 0,15%; compressive strength – 180 MPa.

4.3 Characterisation of the corrosion factors

The investigation pointed at the bio and chemical corrosion of the travertine, deformation of lead sealing at the joints between granite blocks due to vibrations caused by traffic, deterioration of lime mortar between travertine slabs, efflorescence from the open granite joints of external stonework. The assessment of the condition of the concrete support structure pointed to deformations in the load-carrying structures, corrosion of the reinforced concrete: cracking, rusting of reinforcement, and formation of the carbonate salts. The assessment stated that most of the problems appeared to be related directly to the apparent lack of maintenance during its service life and to the ingress of water via open joints and external travertine cladding [8].

In summary, the main problems are related to the further preservation of the external travertine cladding and prevention of the reinforced concrete from the further corrosion.

The essential alteration factors for Roman travertine are atmospheric pollution in the centre of Riga; Nordic climate with frequent freezing/thawing cycles; moisture as catalytic/inducing factor for chemical, biological and physical/mechanical corrosion.

The essential corrosion factor for the reinforced concrete support structure is the ingress of the water (along with SO_2, CO_2, Cl ions) through the damaged lead sealing in granite joints and external travertine cladding.

4.4 Guidelines and philosophy for the conservation

The complex restoration concept for the whole Monument were stated the following: in order to safeguard the continuality of the Cultural significance of the Monument (as symbol of national identity and independence, and safeguard Monument's further inclusion in the live of the society) its necessary to provide a structurally sound and water tight Monument's technical structure.

The detailed solution of the stated aim was determined by the:

- necessity of the water repellent treatment of travertine motivated by the inability of travertine's properties to withstand under the aggressive environment and by the necessity to diminish the moisture ingress in the inner concrete structure;
- necessity to replace the original lead sealing in the granite joints motivated by the inability of the lead's properties to provide the hydroisolation of the joints of the external cladding.

5. Evaluation of the silicone based water repellent products

5.1 Laboratory study

The study was aimed to evaluate the efficiency of the various hydrophobic products in laboratory in order to recommend the protective treatment for the conservative treatment of the travertine.

The travertine cubes (5x5x5 cm) taken from the quarry were treated with 5 silicon based water repellent products (see table 1). All the tested materials are industrial products, except the sodium-alumo-methyl silanolate (N/A6), which has been elaborated in the Academy of

Sciences in Latvia. The methodology of tests involved the water absorption measure by capillarity and total immersion [9]; evaporation; water vapour permeability measurement, the calculation of the real and apparent density, total porosity [10] and drying index [11]. In summary, the treatment was considered successful if the water capillarity absorption is effectively diminished and total absorption is decreased; if the water evaporation and water vapour permeability could freely occur. The data have been reported in the research of the protective treatments for the stone materials used for the construction and restoration of Ensemble of Brethren's Cemetery [12] and in the congress "*I silicati nella conservazione*" (13-15, 02. 2002, Turin, Italy) [13].

Table. 1. Silicon based products applied on the samples of Roman travertine.

Effective ingredient	Concentration	Carrier agent	Product/company/country
Silane-siloxane	-	water	**K501**/Liquid Plastics Ltd/England
Siloxane	~ 7 M%	aliphatic hydrocarbon	**Funcosil SNL**/REMMERS/Germany
Alkyl-alk-oxy silane	~ 10% (m/m)	water	Funcosil WS**/REMMERS/Germany**
Silicon compound	>10% (m/m)	water	Funcosil OW**/REMMERS/Germany**
Sodium-alumo-methyl silanolate	Si ~ 4,9 V%	water	N/A6**/Academy of Sciences/Latvia**

According to the visual appearance of the treatment, the best products are N/A6 and K501, for the WS and OW the changes are quite slight and did not modify the total appearance of the treated stone. The SNL changes the colour of the travertine significantly to an unacceptable level.

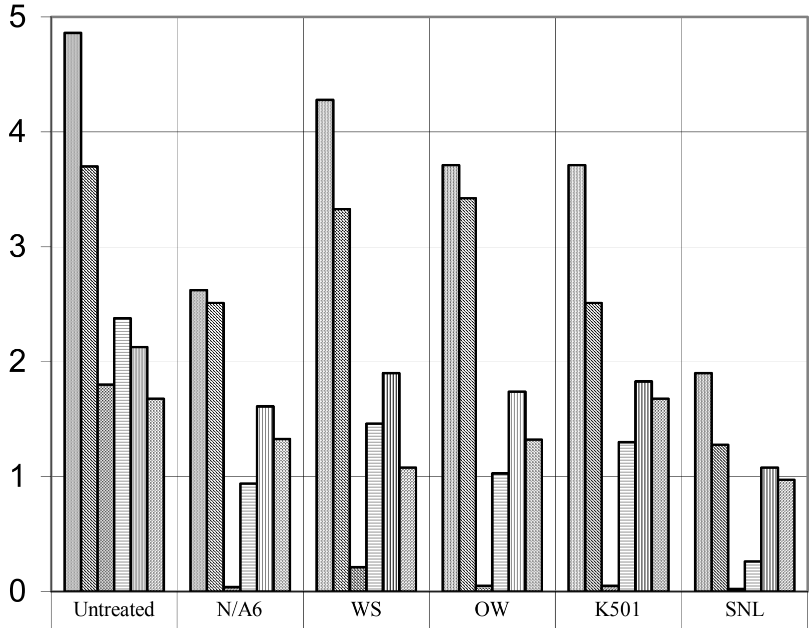
The performance of the hygric properties and changes in porosity of the water repellent products applied on the travertine samples is shown in figure 2.

The sodium-alumo-methyl silanolate N/A6 has diminished the water absorption by capillarity practically to minimum: from the 1,80% for untreated stone to 0,04% for the treated, and has decreased also the total absorption from the 2,38% for the untreated to the 0,94% for the treated. At the same time the product does not limit the water evaporation and water vapour permeability and shows small decrease in drying index (1,61) and WVP (11,33) in comparison to the untreated stone. The N/A6 performs the best properties in comparison to the other products.

The alkyl-alk-oxy silane WS has the lowest diminish of capillary absorption (0,21%) and total immersion (1,46%) in comparison to the other products. However it performs the highest drying index (1,9) and good water vapour permeability (1,08).

The silicon compound OW and silane-siloxane K501 have very close properties in all the tests characterised by the good absorption diminish about 0,05% for capillarity and 0,1% for total immersion and the high evaporation and water vapour permeability values.

The siloxane SNL has the most effective diminish of the water absorption for capillarity (0,02%) and total immersion (0,26%). Although it has limited evaporation water vapour permeability, which means, if the water will get inside into the stone behind the treated layer, it will have little possibility to evaporate. Damage producing factors such as hygric swelling and shrinking, subsequent frost damage caused by a sharp separation of wet and dry zones) should be considered [7]. All over, as this product has modified significantly the visual appearance of the travertine and should be refuse as non-acceptable for the treatment.



	Untreated	N/A6	WS	OW	K501	SNL
Volume of pores [cm3]	4,86	2,62	4,28	3,71	3,71	1,90
Total porosity [%]	3,70	2,51	3,33	3,42	2,51	1,28
Water absorption by cappilarity [%]	1,80	0,04	0,21	0,05	0,05	0,02
Water absorption by total immersion [%]	2,38	0,94	1,46	1,03	1,30	0,26
Drying index, log	2,13	1,61	1,90	1,74	1,83	1,08
Water vapour permeability [g/mhPa]E-10	1,68	1,33	1,08	1,32	1,68	0,97

Figure 2. Porosity and hygric properties of the water repent products on travertine.

According to the obtained data from the evaluation of the efficiency of the water repellent products laboratory it could be concluded that:

- the sodium-alumo-methyl silanolate N/A6 performed the best properties regarding the not modifying the visual appearance of stone after the treatment, reduce of water absorption by capillarity (0,02%) and total absorption (0,94%), the smallest diminish of drying index (from 2,13 for untreated to 1,61 for treated) and vapour permeability (from 1,68 for untreated to 1.33 for treated samples);
- the alkyl-alk-oxy silane Funcosil WS has the highest water absorption by capillarity (0,21%) and at the same time the highest drying index (1,90) in comparison to the other products;
- the silane-siloxane K501 and silicon compound Funcosil OW show very similar properties in all the tests by the diminishe of the water absorption practically to minimum (~ 0.1%), at the same time the drying index and water vapour permeability are high (1,79 and 1,50 accordingly);
- the siloxane Funcosil SNL showed the best diminish in water absorption by capillarity (0,02%), but tend to diminish drying index and water vapour permeability for 2 times (accordingly 1,08 and 0,97). All over, this product changed the visual appearance of the travertine significantly and should be refused as non-acceptable.

The product sodium-alumo-methyl silanolate (N/A6), which has been elaborated in the Academy of Sciences in Latvia, performed the best properties. However this product can't be obtained in the amounts necessary for the practical conservation in object. According to the laboratory data, the water repellent product alkyl-alk-oxy silane WS was recommended for the conservation practice of travertine in Freedom Monument.

5.2 In situ study

The water repellent product alkyl-alk-oxy silane Funcosil WS was applied on the travertine surface after the fundamental restoration works (cleaning by water jet, micro-abrasive sand blasting, re-jointing) were carried out. The hydrophobic product was applied by brushes on the dry stone surface.

The evaluation of the efficiency of the alkyl-alk-oxy silane WS applied *in situ* was carried out in the period of 2 years after the treatment. The intensity of the surface re-soiling was evaluated by the mean of the visual observation, mapping of the decay patterns, microbiological and biological analyses. Microbiological analyses of microscopic fungi and bacteria (nitrification and sulphur), biological contamination with moss and algae were carried out in University of Latvia.

1. <u>Decay patterns evaluated by the visual observation and mapping.</u> A generalized darkening of the travertine after the 2 years of expose can be observed leaving the dark vertical run-off lines on the surface treated with water repellent agent while untreated surface shows uniformities in surface soiling (see figure 3). It could be explained by the hydrophobic nature of the surface on which the water trends to wash off in exact vertical lines. The re-colonisation of the biological growth (mosses, green coloured algae) could be observed. The formation of surface layer on travertine is controlled by intensity and distribution of biological contamination and soiling, as well as by the repellent properties of the surface.
2. <u>Hydrophobic properties evaluated by the visual observation.</u> The visual observation of the treated and untreated surfaces was done during the rain periods. It was stated that travertine shows good hydrophobic properties after 2 years of expose.
3. <u>Evaluation of the re-contamination of the biological growth.</u> Biological analyses showed that the effect of bio-contamination with mosses, algae, microscopic fungi and bacteria among treated and untreated surfaces did not show the significant differences. The amount of microscopic fungi two years after restoration is very similar with slight decrease for treated surface. The presence of sulphuric bacteria in all of the samples points to the high air pollution with SO_2. The presence of the nitrification bacteria was detected only in one sample.

Figure 3. Fragment of the travertine relief of Freedom Monument 2 years after restoration and hydrophobic treatment without any maintenance. Left side of the figure shows the hydrophobic surface, the right side - untreated surface. The untreated surface shows uniform soiling while treated surface has heterogeneous dislocation of soiling in the form of vertical run-off lines.

In the frame of 2 years the protective treatment had not shown inhibition effect on biological growth and the intensity of development in comparison to the untreated stone. The protective treatment did not increase the bio-contamination of the travertine, although the microbial contamination could act as a preliminary precursor for the development of crusts [6]: increases adsorption of airborne particles on the stone surface; enforcing alterations in the capillary water uptake and water vapour diffusion in the rock material. For the treated surfaces the occurrence of biofilms has to be seriously considered due to organo-chemical, polymeric character of hydrophobic substances being susceptible to the microbial attack leading to the loosen of hydrophobic properties of the treated stone [6]. It leads to conclude that the products used for restoration must be periodically checked in order to plan periodic maintenance works.

According to the obtained data from the *in situ* evaluation of the efficiency of the alkyl-alk-oxy silane Funcosil WS after 2 years of exposure it could be concluded that:

- product shows good hydrophobic properties;
- treatment does not have neither inhibition nor catalytic effect on microbiological and biological contamination;
- surface treatment alone have no ability to protect and maintenance the travertine from the further alteration;
- the period of the 2 – 3 years is critical for the travertine in order to the maintenance should be carried out.

6. Use of binary mixed polyurethane mastic for the substitute of the original lead-sealing of the granite joints

6.1 Selection of the restoration material

According to the conservation principles, and architectural/constructive specification of the Freedom Monument, the filling material of the joints between granite cladding and sculptures in the vertical facades should meet the following demands:

- providing the hermetic properties preventing the ingress of moisture and atmospheric pollution into reinforced concrete construction;
- elasticity of the material providing the possibility to deformations due to the thermical and mechanical movement of the Monument materials. According to the calculations, the material should be able to uptake about 2 – 3% of deformations;
- compatibility with the granite by the density (≤ granite) and thermal expansion (similar to granite);
- compatibility with the lead by the expression, appearance, texture and form;
- reversibility of the substitute material.

The traditional materials, such as original lead sealing or lime/cement mortar, cannot provide the necessary hermetic of the joints. Therefore the solution was made to evaluate the possibility to use the modern materials as the most appropriate the binary mixed elastic material of epoxy bounded polyurethane (further in the text PU) was selected.

According to the previously stated demands the polyurethane mastic:

- could provide the uptake of the deformations up to 25% and due to the high elasticity could provide hermetic of the joints;
- has the less density than granite (granite: 2600 kg/m^3, PU: 1200 kg/m^3);
- waterproof material;
- although PU material is not similar to the lead by the surface texture and visual impression, it is possible to obtain the necessary colour identical to the original lead-sealing;
- is reversible and it is possible to take out the harden material from the joints without any damages to the granite.

Although PU provides appropriate properties, the evaluation of the practical experience in the objects and its durability is of great importance. Especially taking into account the comparatively high expenses of the given material. In Latvia the use of the PU mastic instead of the traditional materials for the granite jointing has been started to appear just in the recent 5 years for the construction of the new buildings. Therefore the long-term experience of this material was evaluated in the Finland, where this material has been used for 15 years and the climatic conditions for the exposure are similar to Latvia. The results of the *in situ* observation of the use of PU in the Cultural significant objects in Helsinki (Finland) should be summarised as follows:

- the polyurethane mastic performs good properties after 10 – 15 years of exposure in comparison to the traditional cement/sand mortar used in objects;
- the successful long-term performance of polyurethane material is strongly determined by the accurately considering of the jointing technology stated by the producer.

The main damages, which can occur due to the mistakes and inaccuracy of the jointing technology, are:

- weak bounding between PU and granite and further detaching from the granite;
- mechanical fissures in the PU material.

Among the other damage causing factors, the social factor should be considered, as the material is easy sustainable to the damaging by the action of the man (cutting, impaling, etc.).

6.2 Restoration and *in situ* evaluation

In the frame of the restoration of the Monument, the all lead-sealing of the granite was replaced by the PU mastic. The original lead-sealing was removed mechanically by the mean of hand instruments, the joints were cleaned and prepared according to the manufacturer's recommendations.

The rejointing with PU mastic was done according to the manufacturer's demands and under supervision of the expert from manufacturer's side. Taking into account the construction of the Monument, the possibility of the presence of the moisture under the granite cladding was considered. In order to provide the evaporation of the moisture and prevent the negative side-effects in the long-term period, the drainage of the PU mastic joints was done by the placing in the plastic drains (diameter about 5 – 10 mm) in the joint material in the direct places determined for the construction of the Monument as a whole.

In the period of 2 years after restoration the evaluation of the performance of the PU mastic in the object was carried out by the visual observation and detailed documentation. In summary the following points should be outlined:

- the PU mastic shows good bounding and hermetic properties;
- however despite the carefully carried out jointing work, in few places the damages due to the inaccuracies in the jointing technology was observed;
- the main damages are the mechanical cutting of the jointing material caused by the people. It could be considered as the main disadvantage of the PU material when using it in the places accessible to public.
- the regular every-year survival of the damages and subsequent local repointing of the joints should be done as a further regular maintenance.

7. EVALUATION OF THE FAILURE OF THE Use of binary mixed epoxy based material for the RESTORATION OF granite joints

The restoration of the joints of granite in the terrace of the Monument was another stage of the restoration and was done in the 1999 by the mean of the binary mixed epoxy based material with 10% admixture of the fine-grained quartz sand. Original cement/sand mortar filling proved to be unable to provide the necessary hermetic of the joints, especially taking into account the constructive specification of the terrace and the absence of the thermo-joints. The selection of the epoxy-based mortar was motivated by the necessity of the higher elasticity of the jointing material together with providing of the high mechanical and wear resistance.

The year after the restoration the cracking of the jointing material in the local places was detected. After 2 years the widening of the cracking process was stated. The detailed mapping and documentation of the jointing was done and the results were summarized as follows:

- cracking parallel to the edges of the jointing leading to the detaching of the mortar from the granite;
- cracking perpendicular to the edges of the jointing leading to the damages of the jointing material;
- cracking of the granite near the joints parallel to the edges of the joints.

The evaluation of the factors for the cracking of the jointing material points to the following possible causes:

- the thermal swelling and shrinkage of the building materials due to the fluctuations of the temperature and the non compatibility of the thermal expansion properties of granite and jointing material. The coefficient of the linear thermal expansion of the granite is 8×10^{-6} m/m^0C, while the epoxy based materials have higher linear expansion of about 20×10^{-6} m/m^0C;
- the mechanical vibrations caused by the nearby traffic;
- insufficient elasticity of the epoxy based material to adapt the changes of the granite parameters.

The failure of the use of the epoxy based material and the subsequent damages were caused due to the insufficient previous evaluation of the compatibility of the properties of the granite and given epoxy based material, as well as the suitability of the given jointing material for the given case study. Taking into account the parameters of the granite slabs, wide of the joints and temperature fluctuations, the changes of joint's parameters reaches about 2%. The given epoxy based material cannot provide such elasticity and the cracks occur.

8. CONCLUSIONS

According to the study of the use of new materials in the conservation practice of the Freedom Monument, the following conclusive remarks could be outlined:

1. The laboratory evaluation of the silicone based water repellent treatment on travertine samples showed good results of effective diminish of water capillarity absorption, decrease of total absorption and possibility for water evaporation and water vapour permeability occur through the hydrophobic layer.
2. The *in situ* evaluation of the conservation of stone material by the mean of surface treatment with silicone based water repellent product showed that:

- despite the good water repellent properties showed *in situ*, the hydrophobic treatment alone have no ability to protect and maintenance the stone material from the further alteration;
- due to the changes of the properties of the stone surface from hydrophilic to hydrophobic, the proper changes in the dislocation of the surface deposition should be considered leading to the changes in the visual appearance of the object as a whole.

3. The use of the binary mixed polyurethane mastic for the jointing of the granite material should be evaluated as follows:
    - material provides all previously stated demands in regard to the hermetic and elastic properties of the joints and could be considered as good solution for preservation of the technical condition of the object;
    - material did not respect the traditional practice of the jointing of granite and therefore the criticism could be provide in regard to its use;
    - however the reversibility of the material provide the possibility for the long-term period to elaborate the better solution.

4. The failure of the use of epoxy-based material for the jointing of the granite material occurred due to the:
    - insufficient previous evaluation of the compatibility of the physical/mechanical properties of the granite and jointing material;
    - insufficient previous evaluation of the specific in construction of the given object and subsequently incorrectly stated demands for the jointing material.

5. The products used for conservation/restoration must be regularly checked and the detailed documentation should be carried out in order to:
    - plan timely the further maintenance works of the given object;
    - formed the data base of the experience of the use of the new materials and their performance *in situ*.

6. The methodology and system used for the documentation and evaluation of the conservation materials *in situ* should be of objective character in order to provide possibility to correlate the obtained data between various objects and regions throughout the long-term period.
7. The maintenance is vital for the further preservation of the present state of the restored object and the period of the 2 – 3 years is critical the maintenance has to be carried out.

9. BIBLIOGRAPHY

[1] Amoroso G. G., Fassina V., *Stone decay and conservation, Atmospheric pollution, cleaning, consolidation and protection*, Del 1, Materials Science Monographs, 11, Elsevier Science, ISBN 0-444-42146-7, 1983, pp 221

[2] Ashurst J., Dimes F. G., *Conservation of Building and Decorative Stone*, Vol. 1., Butterworth-Heinemann, ISBN 0-7506-1268-1, pp 162-173, (1990)

[3] Bell D., *Guide to International Conservation Charters*, The Historic Scotland, Edinburg, ISBN 1-900168-24-3, (1997)

[4] J.&N. Ashurst, *Practical building conservation*, Vol. 1., Stone masonry, Gower Technical Press, ISBN 0 291 39745 X, pp 92-95, (1988, reprinted 1989,1990)

[5] K. Sandin, *Influence of cracks on moisture conditions in facades with water-repellent treatments*, Internationale Zeitschrift fur Bauindstandsetzen, 5. Jahrgang, Heft 5, pp 499-522, (1999)

[6] J. Th. Warsheid, *Impacts of microbial biofilms in the deterioration of inorganic building materials and their relevance for the conservation practice*, Internationale Zeitschrift fur Bauindstandsetzen, 2. Jahrgang, Heft 6, pp 493-503, (1996)

[7] E. Wendler, *New Materials and Approaches for the Conservation of Stone*, Saving our Architectural Heritage: The Conservation of Historic Stone Structures, Edited by N.S. Baer&R. Snethlage, John Wiley&Sons Ltd., pp 181-196, (1997)

[8] Sidraba I., Krage L., Igaune S., Vitina I, *Corrosion and restoration of travertine and granite in the Freedom Monument (Riga, Latvia)*, Understanding and managing stone decay, edited by R. Prikryl&H. Viles, Karolinum Press, pp 99-108, (2002) (in press)

a. M. A. Teutonico, *Laboratory manual for Architectural Conservators.* ICCROM, Rome, (1988)

[9] DIN 52615, Bestimung der Wasserdamppfdurchlassigkeit von Bau- und Dammstoffen

[10] NORMAL 29/88, *Misura dell'indice di asciugamento,* CNR, ICP

[11] Krage L., Sidraba I., Vitina I., Lagzdins E., *Evaluation of the Effectiveness of Protective Treatments for Limestone of Riga Brethren's Cemetery.* Water Repellent Treatment of Building Materials. F. H. Wittmann edited. AEDIFICATIO Verlag GmbH, ISBN 3-931681-25-4; pp 153-166, (1998)

[12] Sidraba I., Krage L., Graudums I., *Necessity and efficiency of conservation treatment on travertino romano*, int. conf. "I silicati nella conservazione", Fondazione per le Biotecnologie, Torino, February 13-15, (2002)