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Assessment of damp and salinity of historical building in Markušovce

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Abstract. This article deals with diagnostics and current state of historical building in the grounds of the manor house Markušovce, eastern Slovakia. In the introduction, the problems of historical building, materials and structures are discussed. The next part is devoted to assessment of the selected structures, moisture survey and salinity above all. Determination of salinity shows high concentrations of chlorides, in part due to maintenance of local roads, which is in the immediate vicinity of the building.. Also, the high damp content of the masonry was confirmed due to the lack of waterproofing as well as high levels of groundwater. Near the historical building is a river Hornád that this fact suggests. The proximity of the park with trees and grassing turn causes shading of western and northern facade parts. The damp and shading of façade parts contribute to bio-corrosive manifestations, increased growth of moss and algae on the façade, and also confirm corrosion of masonry evidenced by higher sulphate content due to biogeneous sulfuric acid. The results of diagnostics tests show, that the samples from damaged parts of façade have a higher degree of salinity, this fact confirms the need for a reconstruction.

1 Introduction

In today´s era, historical buildings are frequently having problems with damp. There are four main sources of dampness in building, rising damp, penetrating damp, water from leaks (pipes bedded) new buildings an additional problem is trapped construction water. Structural movement and consequential cracking can form obvious paths for water to penetrate a wall. Similarly, frost erosion caused by atmospheric impurities can reduce a wall's resistance to damp penetration. These phenomena are influenced by chemical attack from environment.

In the times of their construction there were no moisture insulation used to insulate the ground from the construction systems. Moisture is a major source of deterioration of technical state and corrosion processes in historic masonry constructions. Rising damp is a natural phenomenon which occurs when groundwater flows into the base parts or pore structure of a masonry construction. From practical experience it is known that many other factors may play a role regarding permeability problems in masonry. The amount of possible causes of moisture problems in historic masonry underlines the complexity of this phenomenon. Evaporation is an important factor in rising damp. The surface of an affected wall contains moisture that has risen from the ground and this moisture is then subject to evaporation. The factors controlling evaporation include: temperature, humidity, air movement and surface [1].

Also, damp in constructions has significant effect on indoor climate when the relative humidity of indoor air rises. High relative humidity creates molds at the wall surfaces, most of them at the lower places, where are the lowest surface temperatures.

Historical buildings not commonly used, such as manor house, have serious problems with molds because of poor ventilation. The subject of the article is the assessment of the current state of the former technical building in the grounds of the manor house Markušovce. Methodical procedures of diagnostics this historical building are discussed in contribution.

2. Material and Methods

2.1 Historical building in Markušovce- insights from the input inspection

Markušovce is a village and municipality in the Spišská Nová Ves District in the Košice Region of central-eastern Slovakia. Markušovce was founded in the 12th century before the Tatar invasions of the region. The village was owned by the Mariassy family from the 13th century, and many members of the family are buried in the village's Church of St. Michael. The manor house of Markušovce was built in 1643 and is now a museum, together with the Rococo belvedere (or garden house) „Dardanely", dating from 1778, which stands in its grounds; this contains a collection of musical instruments and is frequently used for concerts [1].

There is also a historical building in the grounds of the manor house, but is without making public visits available. This damaged historical building (see figure 1 - in midle part of photo), is at present time registered in the list of Monuments Board as Technical Building. The assessed building dates from the 18th century and was built in the Baroque style [1].

During the visual survey of object it was found that damp content of the internal masonry pillars reaches up to the height at around 1700 – 1900 mm. The situation was the worst at the north and west side of the technical building. On the inner surface of the plasters there were visible efflorescence and mildew occurrences especially in the higher parts of the plinth. On the outside of the walls there are still visible lichens, mosses and algae.

The biggest problem was the partially destruction of roof of building, which is source of negative influence of the water towards the walls, mortars, plasters and reason of foundations disrepair. The neighboring building was renovated aproximately 5 yers ago (see figure 1 - right side in the photo).

Figure 1. Manor house Markušovce in region Spiš (Slovakia) and assessed building *(owner photo*).

Usually natural damp of building construction is not a technical problem. Every material in natural environment even after application contains certain amount of water on the surface or inside structure. Total content of water is closely connected with character of structure of materials, but also with the way and location of their build in. When we take this into consideration, water chemical composition due to real circulation in environment (the presence of water pollutants etc.), in the structure of building materials appears chemical and chemical - physical processes. These processes are initiated by pollutants by specific thermodynamic conditions and by time links [2]. In building constructions the most important are physical processes as soaking, damping and drying. The main types of such processes in building are soaking, damping and drying, he related degradation processes as well as effect lies in the formation of mold, growth of algae, etc. [3]. Dumped part of construction is very favorable for mushrooms.

When chemical pollutants are present in water in soluble form, after evaporation of liquid phase, on the surface is likely to build up their concentration or inside the construction in the form of crystals or new products - efflorescences. The pollutants may also participate in chemical reactions in structure of

materials. Production of new products can be connected with volume changes, which are the most clear at crystallization processes [3]. All volume changes are linked with mechanical consequences which are visible in increased tension, decreasing of strength parameters or even destruction.

Figure 2. Damaged part of east side of façade, damp, salinity and biocorrosion *(owner photo*).

2.2 Methods of diagnostic of historical building

Various diagnostics methods can be used to study parameters such as damp, mechanical properties of construction, salinity (presence of salts and efflorescences), thermal parameters and other. This way, the methods are classified according to their functioning principle, allowing choosing each technique independently of the failure diagnostics.

An investigation of the effects of humidity and salt crystallisation on masonry has been undertaken at the historical building in Markušovce. The chemical - analytical methods for the assessment of mortars and plasters of facades due to biocorrosion will be under consideration. Assessment of degradation masonry consisted of determination of moisture and salinity as combination of gravimetric and chemical analysis of obtained samples from most damaged part. It's important to understand that one method can be used for multiple problems that are present on the building. The article discusses in particular the results of the material test in terms of degradation. However, a static survey was also carried out showing that part of the building was in an emergency.

2.2.1 Determination of damp. Regarding the results of the diagnostic survey the mass of humidity (w_{mh}) samples were determined by gravimetric method, samples were weighed and placed into a laboratory drier ELOP 1200, at 105±5°C. The drying process was carried out in 3 stages. In the first step, samples are dried for 2 hours, in the second stage 6 hours, in the third stage individually up to the constant weight of the samples. After each drying, the samples were weighed. The mass humidity (w_{mh}) calculation was according to the equation (1):

$$w_{mh} = \frac{(m_w - m_d)}{m_d} \cdot 100\% \quad (1)$$

where: w_{mh} - mass humidity, m_w - mass of wet sample, m_d - mass of dray sample.

To determine the water content in structure of building material we can used different portable devices as well, but gravimetric determination is more accurate [3].

2.2.2 Determination of salinity. Masonry within the building has been contaminated with chloride salts above all, which are undergoing cycles of crystallisation - dissolution in response to fluctuations in relative humidity.

This problem which affects the durrability is related to the salt migration processes in the building construction. The presence of aggressive saltes is limiting criterion for production novadays silicates

too [3]. Presence of salts in mortars is also observe and within evaluation according to WTA rules for reconstruction purposes [7] concentration of salts is expressed as salinity.

To gain quick results In situ, portable kits are used to semiquantitative determination of chlorides, nitrates and sulphates. Determination of chlorides in laboratory conditions is based on either on partial decomposition of sample by mixture of acids and following determination, or by determination of chlorides from liquid leaching of the silicate sample. Range and accuracy of these determinations is influenced by several factors. For accurate analytical determination is best to used potentiometric determination with use of specific ion selective electrode [2]. Potentiometric determination of chlorides is more useful from practical point of view in compare with clasical determination such as gravimetric method or argentometric titration.

To the determination of sulfates, the gravimetric method (precipitation of sulphates from the dissolved form of silicate samples into the insoluble form of $BaSO_4$ according to the chemical equation (2) was used most frequently. Sulphate content was calculated after ignition of $BaSO_4$.

$$BaCl_2 + SO_4^{2-} \rightarrow BaSO_4 + 2\,Cl^- \quad (2)$$

However, the determination is time-consuming and requires, in particular, lower analytical capacity and precise monitoring of the method, especially in the case of lower sulphate concentrations, therefore, in particular, direct powder determination using the XRF method is currently used. To determine precise structural changes RTG analysis and SEM or EDX microscopy are used.

Circulation of nitrogen in environment is greatly affected by anthropogenic activities, by which is its concentration increased even in waters. Influence of nitrogen salts is observed in connection with silicates for the reasons of corrosion by leaching. According to WTA rules [7] the presence of nitrates increases salinity of mortars. At periodic changes of humidity inside construction, concentration of nitrate salts, formation new corrosive product and crystals in finale phase even destruction signs will happen. Increased concentration is probably likely for oxidation- reduction reaction of certain forms of nitrogen in natural environment reasons [2].

Nitrates can be quite fast determine by potenciometric method, with the help of ion selective electrode but disadvantage is likelihood of interference of some ions. Another analytical method for nitrates determination is spectrophotometry.

3. Results and discusion

Several physical factors affect the humidity in the masonry. The presence of salts in massonry increases the w_{mh}, because salts have hygroscopic properties [4] and these consequently also enhances the chemical degradation of the masonry. The obtained values w_{mh} (see table 1) were different for the individual materials and also according to the orientation on the world sides of the façade, essentially reflecting the long-term negative effects on the masonry construction.

Based on the experimental determination of humidity expresed by results w_{mh} and according to the criteria given in [6], was confirmed that the content of the water phase in the structure of the masonry is individually distributed. The obtained w_{mh} values in the range from 7.5% to 10% means high humidity, values above 10% very high humidity respectively, which are created in any case suitable conditions for masonry biodegradation. Biocorosion of facades effect the quality of building envelope causes the changes with integrity, chemical composition, mechanical properties, thermal characteristics, fire resistance and changing aesthetic properties and appearance. These serious issues need to be monitored.It is possible to conclude, that the long-term negative effects of the environment as well as the way of maintenance appear on the present technical state of masonry structure.

Determination of chlorides c(Cl) concentration, (as selected representative salts) was provided by potentiometric method using selective chloride electrode. Alkality changes of samples were expressed as pH values, the potentiometric method was chosen for their estimation. Table 1 shows the comparison of the average results of stone samples and bricks taken from facade at the same height from the ground about 300 mm.

The results of diagnostics tests show, that the samples from damaged parts of façade have a higher degree of salinity, this fact confirms the need for a reconstruction. The samples taken from the stone-redominantly porous sandstone are able to absorb humidity and consequently salts are deposited into wall of pores. The presence of salts has also been observed at the surface of the sampling points as white efflorescences. Increased salt concentrations are related to the location of historical building, as

we can see from figure 1 and figure 2, the building is located in the immediate vicinity of local communication where salt is used for winter maintenance.

Except to chlorides, higher sulphate concentrations were also detected in the samples using semiquantitative analysis by $BaCl_2$ precipitation of sulfate anions. In addition to above mentioned method was made FTIR spectral analysis of sample by ATR FTIR spectrometer Alpha Brucker, in range 4000-360 cm^{-1}, with 24 scans. The results of white salts sample taken from the east part of the facade is shown in figure 3.

Table 1. Results of analytical determination of mass humidity and salinity.

Orientation of facade	Type of sample	w_{mh} ±0.01%	pH ± 0.01 [-]	c(Cl)± 0.01%	Degree of salinity [7]
east	stone	5.64	9.11	0.285	high
	brick	10.64	8.95	0.334	high
south	stone	3.64	10.42	0.276	high
	brick	5.58	9.14	0.380	high
west	stone	8.16	7.83	1.74	very high
	brick	11.71	8.25	1.15	very high
north	stone	7.42	6.95	0.85	very high
	brick	16.45	8.02	2.47	very high

To simplify the analysis of the results of the vibration spectrum is presented in three main regions relating to: vibrations of the sulfate ions 500-1300 cm^{-1}, bending vibrations of water molecules 1610–1660 cm^{-1} and the water stretch region 3000-3800 cm^{-1}[2]. IR spectrum shows the intensive peak of a wave number of 1086 cm^{-1} corresponds to $CaSO_4$ due to sulphate degradation [4].

In figure 3 three characteristic FTIR transmitance spectra samples obtained from east facade are presented. The spectra from sample brick (2) and sample mortar (3) have dominated the characteristic peaks of calcite (1400 cm^{-1} and 880 cm^{-1}) while a weak broad band of approximately 1100 cm^{-1} is an indication of silicate (-Si-O) vibrations, which are overlapped the peak of the anion -SO_4^{2-} in both cases.

Finally the spectrum obtained from sample salt (1) has dominated the characteristic peaks about 1650cm^{-1}, 1064cm^{-1} respectively at 620cm^{-1} which are an indication of sulhpates [5], guiding us to conclude that the sample contains products of bio-corrosion processes, because on the historical masonry cement was not used as a binder.

Although IR spectroscopy is one of the most widely used physical methods of investigation of molecular structure, information about the crystal's structure can be useful to interprete the IR spectra established by X-ray diffraction methods.

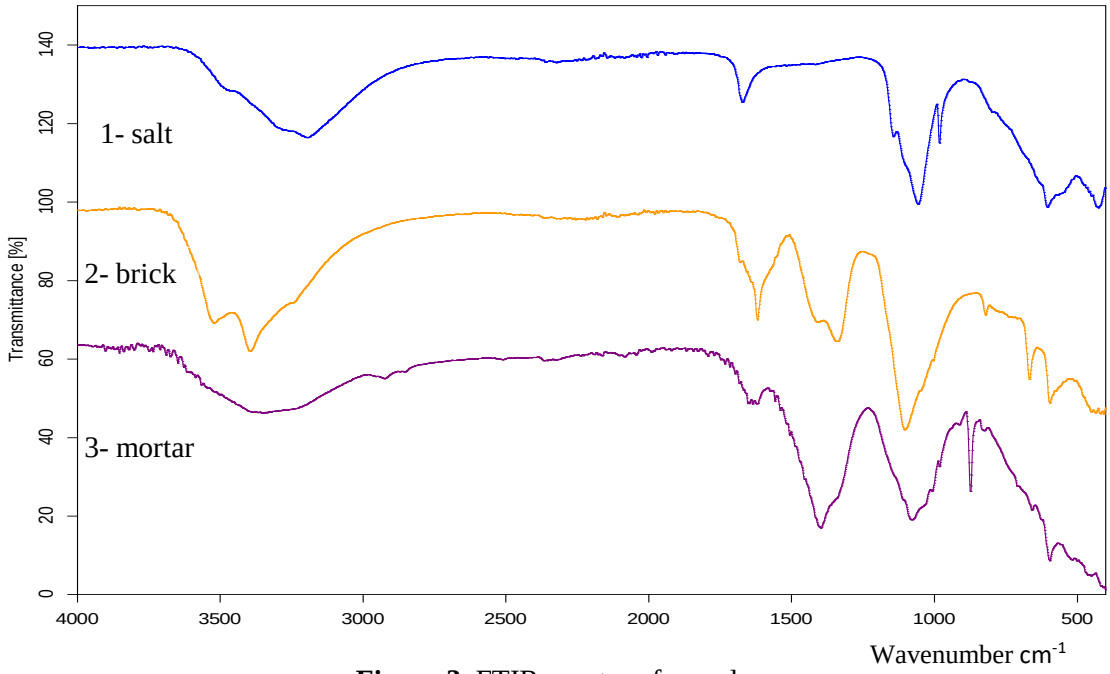

Figure 3. FTIR spectra of samples.

4. Conclusion

The results of diagnostic assays show, that the samples from damaged parts of façade have a higher degree of salinity, this fact confirms the need for a reconstruction. Determinations of humidity and salinity of construction parts are very important aspects from durability and reliability building. Damaged parts necessarily require urgent reconstruction because the object is in several parts of statically disturbed. When choosing technologies and materials, it must also be taken into account that it is a historic building, each other step should be in accordance with the requirements of the monumental authority under which the object belongs.

Refurbishment of historical building also must be taking into account:

- the general requirements for the protection of other historical monuments and environment in areal of castle Markušovce,
- selection and application of suitable remedial materials compatible with historical masonry.

At the same time, account must be taken on the technical needs and social requirements for the use of building during the reconstruction, cultural and tourist activities and events in areal of manor house of Markušovce.

Acknowledgements

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