Technology of Additional Impermeable Layers and Its Use in Restoring of Historical Buildings

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Abstract. Moisture and its negative effects on monuments are a widespread problem that needs to be tackled especially to save historical buildings. The moistening of objects, whether historical or new, is not only part of our climate zone, but can be attributed to a global character, as evidenced by a number of publications and research on the issue of water logging of buildings that date back to 1892. It is not only a threat to the preservation but also the functionality of historical structures, because it is responsible for reducing the mechanical performance of the masonry, as the presence of water in the pores of the building material negatively affects the tensile strength and also the compressive strength. It also causes degradation of these materials, which can be constantly exposed to cyclic freezing and subsequent thawing, biodegradation and migration and subsequent crystallization of salts. Moisture also contributes to increasing the thermal conductivity of these constructions, resulting in high energy consumption for heating. Last but not least, we can associate various respiratory diseases of people living in this environment with moisture. Due to the serious effects associated with rising damp in the masonry, water capillarity is rightly considered a key factor in the protection of heritage. The origin of moisture can be attributed to several facts, but in the present research we focused mainly on rising damp and its negative impact on historical structures. The paper will summarize the results obtained so far and conclusions from various authors investigating the technology of additional impermeable layers. Subsequently, we will analyze and describe the obtained measurement results before and after the use of undercutting technology on two specific historical buildings in Slovakia. All the research and measurements were carried out in situ, which helped us to achieve objective results, the outcome of which is this work. The measured values show a significant drying of the structure above the plane cut and a positive effect on the repaired structure. The research also encourages further investigation of moisture acting mainly below the level of new insulation and its impact on masonry.

1. Introduction
Rising damp is one of the most significant and widespread problems, not only of our climate zone, which have a significant impact on the architectural heritage and a significant part of historical buildings, as evidenced by a number of publications [1, 2, 3]. This problem can be illustrated by the example of Belgium, where more than half of the restoration of monuments is related to high humidity and salinity of structures. Its origin can be attributed to a number of factors such as various random causes related to water penetration from pipelines, rainwater pipes, water vapor condensation, capillary action, water vapor diffusion, absorption and many other phenomena. This moisture seriously compromises the preservation but also the functionality of the historical structures, as it is
responsible for reducing the mechanical performance of the masonry, as the presence of water in the pores of the building material negatively affects the tensile strength and also the compression strength. It also causes degradation of these materials, which can be constantly exposed to cyclic freezing and subsequent thawing, biodegradation and migration and subsequent crystallization of salts. Moisture also contributes to increasing the thermal conductivity of these structures, resulting in a high energy consumption for heating. Last but not least, moisture can be associated with various respiratory diseases of people living in this environment. The problem of moisture and its impact not only on construction but also on the human health is a long-standing problem that was described early in 1892, when H. R. Kenwood published a work [4] describing the effect of this moisture on people living long-term in this environment. This has been overlooked for many years and was not considered a real threat. Today, it is clear that this problem must be tackled, as the removal of moisture can be considered a key factor in the protection of cultural heritage. Nevertheless, the removal of rising damp from historical structures is still extremely difficult [5], despite the fact that the phenomenon of rising humidity in historic buildings has been studied for quite some time [6]. As a result, the effect of moisture on the structure is often unprofessionally eliminated, but not the cause of moisture. This will cause the failures to reappear over time, resulting in the need for additional work and costs. There is often a problem, especially from the point of view of the implementation of the Venice Charter, the observance of which often prevents the implementation of certain remediation technologies on listed buildings. This results in the negative attitude of some monument protection authorities towards technologies that significantly undermine the integrity of structures. Unfortunately, from the international point of view, the issue of assessing the dehumidification of historical structures is very closely dealt with, as evidenced by the number of scientific articles and publications compared to the publications dealing with moisture itself and its formation. For this reason, many articles on the issue are inaccurate and unprofessional, even not supported by any research. This leads to many misunderstandings in the solution of this issue and allows the enforcement of many unverified, dysfunctional technologies on the market.

2. Division of technologies for remediation
To create an overall idea, it is worth mentioning technologies that are used in combating moisture not only in historical constructions. In many articles and publications, we read about the different subdivisions of these methods, both at home and abroad. In the article by R. W. Sharpe [7] of 1977, the classification of these methods into so-called traditional and unconventional. The first group includes technologies ensuring the impermeable layer. It belongs to the group of non-traditional electroosmotic systems and injection systems. A similar classification can be observed in several foreign publications [8]. According to the EMERISDA project, which stands for "Effectiveness of methods against rising damp in buildings" and their output [9], methods for rehabilitating historical structures are divided into two main ways under which the different types of technology fit. However, it is true that these divisions are mentioned in many foreign articles, but there was no possibility of finding out, which led to the technologies in question being assigned to certain groups. The division of these technologies is also described in the literature [10]. It could be considered as one of the most understandable as the technologies for the rehabilitation of moisture according to the constructional and physical point of view divide into seven main groups:

- Ventilation technologies (Knapen's channels, cavity floors,…)
- Technologies for the creation of additional impermeable layers (undercutting masonry, driving stainless steel sheets,…)
- Crystalline screen technology (injection, infusion)
- Technologies using electro-physical principles (passive / active electroosmosis,…)
- Technology of construction heating (concealed heating, microwave drying,…)
- Additional technologies (remediation plasters, waterproofing coatings,…)
- Related technologies (drainage,…)
In the Czech literature [11] we can also find the classification of these groups into direct methods and indirect methods. Among the direct Witzany ranked the first 6 major groups listed above, the seventh group ranks among the indirect methods of rehabilitation of damp structures.

In this work, there will be an overview of research papers dealing with undercutting technology and subsequently described concrete researches of authors, which were realized on two historical buildings in Slovakia. The principle of this remediation method lies in the implementation of a new horizontal, respectively. vertical waterproofing, so-called waterproofing an insulating screen, the application and positioning of which is ensured by insertion or insertion into the cross-section of the structure [11, 12, 13, 14].

3. Undercutting technology principle
Masonry undercutting is, as a technology, one of the common technologies designed to realize a new storage gutter for waterproofing in walls [46]. Modern technologies allow undercutting on various types of masonry (stone, brick, mixed, ...) as well as different thicknesses. The working width for forming the storage joint is approximately 0.3 to 0.5 m. Subsequently, before inserting additional insulation, it is necessary to clean the gutter from debris of mortar, resp. masonry in order to ensure the smoothness of inserting strips into joints. After cleaning, the waterproofing is applied and the joint is also covered with hardwood wedges or anti-settling plastic. Care must be taken to cover the individual waterproofing, which should be about 5 to 10 cm. After pecking, the next shot is taken. After undercutting, placement of insulation and wedging, PVC pipes can be fitted into the structure and the structure can be plastered. Once the plaster has hardened, the joint is filled with expansion mortar. To ensure the efficiency of the system, it is also necessary to connect the additional insulation from the inside of the building to the horizontal insulation of the floor, respectively. with vertical construction insulation.

4. Overview of the use of undercutting technology
Undercutting technology can be considered as an effective method to combat rising damp. Schmidt also describes this technology in his article [15], which deals precisely with one chapter of undercutting technology and describes it as radical and costly, but considers it to be very effective. As an example, a study [16] describing the use of diamond rope undercutting (HIO-technology) [17] dealing with the redevelopment of a former business academy in Zrenjanin, Serbia, dating from 1892 in the city. Detailed description of the redevelopment of the building was divided into 3 steps, which are described in detail in the article. The authors state that the technology eliminates 100% rising damp, because all horizontal surfaces of sanitized walls are cut off as low as possible from the ground, or from the basics. The authors also state that they designed the method mainly because of the high moisture content, which resulted in the crystallization of salt and the object required rapid and radical intervention. They also consider this technology to be fast, efficient and economical. The implementer of the technology [17] mentions many references, mainly from Serbia, Hungary and Romania, where it describes its use in more than 260 churches and hundreds of other buildings. From this point of view, we could consider the technology to be widely used and used abroad, especially in a similar band as in our country.

Another example is the article [18], which describes and analyzes the method of total cut using ultra-fast wire at the University of Priščina, with using a wire with titanium edges, or a diamond wire and then inserting special ribbed strips.

Undercutting technology and its implementation have been studied in several places around the world. For example, the research and implementation of this method on various buildings in Italy [19, 20].
It should be noted that the method is not suitable for all objects, and several ineffective attempts of a method based on the creation of an additional impermeable layer are also noted. This problem can be attributed to inappropriate design of the required technology, but also to improper implementation [21].

5. Results of in situ research
Research is focused on obtaining moisture values of historical structures before and after realization of in situ remediation with the help of undercutting technology. It is primarily necessary to demonstrate the effectiveness of the technology in question and its necessary implementation in cases where other technologies are insufficient. Fair values measured directly on historic structures will clearly demonstrate the effectiveness of the technology, even if the integrity of the historic structure, where this moisture insulation was not originally found, has been compromised. The results described in this article correspond to two historical objects in the territory of the Slovak Republic. These studies can be divided into values before the implementation of the undercutting technology. These values are intended to give an idea of the state of the object and will also serve as comparative values for subsequent measurements. Following the undercutting technology, further measurements were taken to demonstrate the rate of drying of the structure.

Individual values of humidity have been recorded in the tables and selected values can be observed in Table 2 and Table 3. Since in Slovakia the classification of humidity to degrees has no support in the natural sciences and is only what the legislators believe [10], it is used in the described research. Also in practice the division according to the Czech standard ČSN P 73 0610, which divides the humidity into 5 degrees, which is represented in Table 1.

| Place of measurement | Measuring height from floor [cm] | Mass moisture [%] | Measuring height from floor [cm] | Mass moisture [%] | Comm. |
|----------------------|---------------------------------|-------------------|---------------------------------|-------------------|-------|
|                      | Date 16.5. ‘17 20.6. ’18 14.9. ‘18 |                   | Date 16.5. ’17 20.6. ’18 14.9. ‘18 |                   |       |
| A                    | 50 12.0 2.0 1.8 100 4.3 6.8 2.4 | Facade           |                                 |                   |       |
| B                    | 30 6.0 3.7 2.4 120 7.4 6.6 4.6 | Facade           |                                 |                   |       |
| C                    | 10 9.1 3.7 1.5 180 4.4 1.4 1.9 | Interior         |                                 |                   |       |
| D                    | 10 10.6 3.7 1.8 180 1.2 1.1 1.3 | Interior         |                                 |                   |       |
| E                    | 30 17.5 2.7 2.8 100 17.4 14.3 2.5 | Interior         |                                 |                   |       |
| TAir [°C]            | 24.4 29.5 25.5 |                   |                                 |                   |       |
| Φ [%]                | 82.3 46.3 62.9 |                   |                                 |                   |       |
| TWall [°C]           | 16.4 21.8 24.3 |                   |                                 |                   |       |

Table 1. Degree of moisture of constructions, ČSN P 73 0610 [22]
Table 3. Results of humidity measurements on historical building in Trnava

| Place of measurement | Mass moisture [%] | Measuring height from floor [cm] | Mass moisture [%] | Measuring height from floor [cm] | Comm. |
|----------------------|-------------------|---------------------------------|-------------------|---------------------------------|-------|
|                      | Date              | 7.7. '18                      | 18.11. '19        | 7.7. '18                       | 18.11. '19 |
| A                    | 30                | 17.3                          | 1.4               | 150                             | 2.2   |
| B                    | 30                | 9.2                           | 1.7               | 150                             | 2.7   |
| C                    | 30                | 16.6                          | 1.6               | 150                             | 11.8  |
| D                    | 30                | 14.3                          | 2.0               | 150                             | 6.0   |
| E                    | 30                | 12.5                          | 1.7               | 150                             | 8.7   |

| T_Air [ºC]          | 27.5              | 14.0                          |
| Φ [%]              | 69.0              | 70.0                          |
| T_Walls [ºC]       | 22.4              | 19.5                          |

6. Conclusions
From the results of the measurements it is obvious that the objects show a considerable drying up of the reconstructed structures after a relatively short time. From this point of view, the technology can be considered as very effective despite the considerable laboriousness and cost. Despite their destructive nature, these technologies can help to save historic objects and structures that exhibit high levels of moisture. It is estimated that the positive effect will extend the lifetime of the building and will also help to protect this cultural heritage, despite the fact that the intervention will undermine the original integrity of the structure. It should be noted that in some cases a radical solution is the only possible solution that will help to heal these structures. This research requires many uniform measurements of several historical objects in order to draw clear conclusions, and it is also necessary in the longer term to examine the structure below the cutting plane, and there is a presumption that this structure will be heavily loaded with moisture, which may pose a problem that will need to be avoided.

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