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# The destructive influence of external factors on building partitions in historic buildings

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## Abstract

The article presents the destructive influence of external factors on building partitions in selected historic buildings made from made full-bodied solid ceramic bricks. The external factors are an additional element that adversely affects the maintaining of historic buildings in a good technical condition, and they are complementary to a number of harmful factors that destructively act upon on such buildings. In order to estimate the range of damage in historic buildings, selected buildings that have been exposed to external factors for a long time in the Podlaskie and Warmińsko-Mazurskie Voivodships were analysed.

**Keywords**: capillary moisture, salinity, corrosion, historic buildings

## 1. Introduction

Historic buildings were, in most cases, built of full-bodied solid ceramic bricks. Unfortunately, in a large number of these buildings, we can observe excessive wall dampness (mainly capillary moisture). The reason for this excessive wall dampness is damage to damp-proof insulation or the lack of such insulation. The lack of insulation is due to the fact that horizontal insulation of walls was not used in Poland until the 1920s. As a result, buildings erected before this date have no damp-proof insulation (Gosztyła, Pastor, 2013; Jasienko, 2003).

The excessive dampness of partitions gives rise to corrosive processes that lead to, for example, the salinising of the partitions. If conservation works, mainly the application of a damp-proof course, are to be effective, the distribution of moisture in the wall and the type and concentration of salt in the wall must be measured (Matkowski, Pawlonka, 1982; Nurnberg, 2001; Wesołowska, 2016).

## 2. Wall dampness and its effects

The degree of wall dampness depends on many factors, both biological and atmospheric. The biological factors include unfavourable terrain conditions around historic buildings, the level of free groundwater, the depth of the building's foundations, and the uncontrolled growth of plants surrounding the building. The atmospheric factors include fluctuations in air temperature and humidity. Significance must also be given to the improper maintenance and use of buildings as well as the physical and chemical properties of the materials used in the walls, which affects, inter alia, the level of capillary moisture absorption (Andreas, 1981; Gosztyła, Pastor, 2013; Karyś, 2001).

The excessive damp on the walls leads to the deterioration of living conditions (microclimate) in the building as well as the reduction of the walls' durability because the compressive strength of bricks and mortar, especially limestone mortar, is reduced. The durability of the walls is also reduced by excessive wall dampness accompanied by high salinity (Weber, 2012).

In historic buildings, harmful salts pose a large problem because they gather in the walls as a result of long-term capillary transportation. The presence of salt leads to an increase in the hygroscopic capacity of moisture absorption. The increase of wall dampness resulting from the absorption of air moisture can, in the case of the walls with high salinity, be compared with the dampness caused by the capillary extraction of groundwater. The amount of moisture absorbed from the air depends on the type and concentration of salt in the wall and the relative humidity of the air (Nurnberg, 2001; Wesołowska, 2016). The dynamics of corrosive processes taking place in the walls depend on many factors, the most significant of which are the air quality and the structural integrity of the walls, the main purpose of which is to maintain the bond with the masonry element (Matkowski, Pawlonka, 1982; Wesołowska, 2016).

The harmful effect of salts, mainly chlorides, nitrates and sulphates, is revealed in cracks, discolouration and crystallisation of salt on the surface of the wall. The crystallisation leads to an increase in salt content and, consequently, to the occurrence of tensile stresses. These stresses lead to the destruction of walls through crystallisation pressure, hydrostatic crystallisation pressure, hydration pressure and osmotic pressure. The damp, saline wall undergoes gradual destruction, with layers of plaster and wall coating peeling off. It is also characterised by worse thermo-insulating properties (Jasienko, 2003; Wójcik, 2004).


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## 3. Measuring wall dampness and salinity

The measurement of wall dampness is performed by means of a traditional oven-dry method and other non-destructive methods. One of possible and most frequently adopted non-destructive/non-invasive methods is the use of hygrometers which employ a dielectric measurement method. This method uses the phenomenon of changing the electrical capacity of the material along with the change in its degree of moisture. Other methods (e.g. in situ microwave and neutron methods) are also employed, albeit less frequently (Kęsy-Lewandowska, 1999; Wesołowska, 2016).

The most frequently used electrical methods require scaling because the correlative dependencies between the indication of the meter and the mass humidity depend on the properties of the material, e.g. chemical composition, porous structures, and the type and concentration of saline solution (Nawrot, ????). The researcher's experience indicates that the most precise results can be obtained using the traditional oven-dry method, and this method was chosen to analyse the buildings selected for the article. The buildings are located in the Podlaskie and Warmińsko-Mazurskie Voivodships (Koda, 2005; 2017).

### 3.1. Measuring the level of wall dampness and the concentration of salt

Prior to planning how to improve the condition of a damp building, it is necessary to measure chemical compounds that have a destructive effect on the building materials. For this purpose, the required samples were taken for laboratory testing. One of the remaining criteria affecting the reliability of the measurements is the taking of samples from both the surface of the building partition and the cross section of the wall. This kind of sample taking stems from the fact that dissolved salts can be found inside the walls, while crystallised salts of chemical compounds can be found near the wall surface.

It is important to thoroughly analyse the samples taken from both the plaster and the cross section of the building partition. Concentrating solely on the material taken from the inside of the walls whilst disregarding the samples taken from the plaster gives us a false image of the damage done to the walls by the salts. This stems from the fact that the plaster is often much more polluted by salt compounds than the inside of the wall. The reason for this is the migration of moisture towards the inside of the wall, its drying out, the occurrence of salinity and the structure of the wall (Ickiewicz, Koda, 2018; Kozłowski, Olesiak, 2000). Only a comprehensive analysis of the building partition and the connection between the results of individual measurements can give us a full picture of the destructive effects of dampness and the related issue of the precipitation of chemical compounds.

## 4. Results of dampness and salinity measurements of brick walls in historic buildings in the Podlaskie and Warmińsko--Mazurskie Voivodships (examples)

### 4.1. Description of the buildings

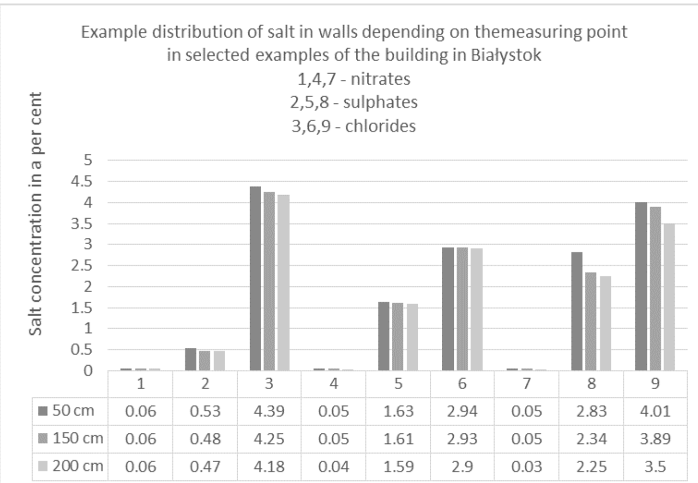
The measurements of the wall dampness were conducted in two historic buildings: a nineteenth-century building located in Białystok and a seventeenth-century building located in Szczytno. The building in Białystok (the so-called "Loża Masońska") was constructed in the years 1803-1806. In 1948, a plan for altering this building and converting it into a city library was drawn up. The interior walls and exterior load-bearing walls, plastered with limestone on both sides, were made of full-bodied solid ceramic bricks, while the partition walls were made of bricks and wood. The foundation walls were made of bricks and stone with cement-lime mortar.

The other building, which currently accommodates the District Court in Szczytno, was erected in the seventeenth century. Its constructional technology is traditional: it is a three-storey freestanding brick building with a cellar. The foundations are made of bricks and stone. The exterior walls are made of full-bodied ceramic bricks with a thickness of 94 cm at the level of the cellar. The ceramic bricks are covered with facing bricks. The cellars were built below the ground level. As a result of mixing building materials in the wall structure (bricks and stone), the problem of huge wall dampness has arisen (Janowski, 1999; Koda, 2005; 2017).

### 4.1.1. Measurements

Due to the historical character of the buildings, measurements were taken with the PWM-3 dampness meter. The dampness meter relies on the phenomenon of the changing of the electrical capacity of the material if its degree of moisture changes. In addition to the measurements of salinity of the analysed partitions, samples were taken from the entire height of the walls, and they were tested using the oven-dry method. This was necessary because of the movement of capillary moisture, the migration of water through the wall and the atmospheric pressure. Moreover, more soluble salts are often found in higher parts of a wall, while less soluble salts can be found in lower parts of a building partition.

In order to determine the presence of the most commonly occurring salt compounds, laboratory analyses were performed according to the established procedure. To determine the presence of the compounds called sulphate compounds (which can occur as sodium sulphate, magnesium sulphate or potassium sulphate compounds), diluted hydrochloric acid was used. The solution was then filtered. To determine the presence of sulphate salts, distilled barium chloride diluted in water was used. In a chemical reaction, sulphates take the form of a white, finely crystallised sediment. By using pieces of paper soaked in various concentrations of barium titrate, the level of salinity of the sample was found. Similarly, dissolved chlorides in the form of calcium, potassium and sodium chlorides were treated chemically in order to determine their presence in a given sample. In order to induce a chemical reaction, silver nitrate is usually used. As with the previous example, after analysis of the results, the presence of chloride compounds in the given material was identified. Sodium, calcium and potassium nitrates most commonly occur dissolved in a diluted hydrochloric acid. In a chemical reaction, nitrate compounds crystallise with both hydrochloric acid and sulphuric acid (Andreas, 1981; Grabski, Nowak, 1957).




| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 50 cm | 0.06 | 0.53 | 4.39 | 0.05 | 1.63 | 2.94 | 0.05 | 2.83 | 4.01 |
| 150 cm | 0.06 | 0.48 | 4.25 | 0.05 | 1.61 | 2.93 | 0.05 | 2.34 | 3.89 |
| 200 cm | 0.06 | 0.47 | 4.18 | 0.04 | 1.59 | 2.9 | 0.03 | 2.25 | 3.5 |

**Fig. 1.** Concentration of salt in walls at the different measuring point heights (Białystok)

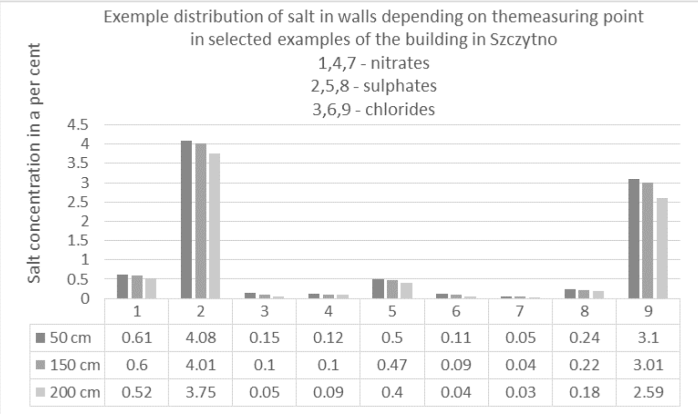
### 4.1.2. Description of activities and research work performed in Białystok

The measurements of wall dampness in the building partitions were taken at the height of 0.5m 1.5 m and 2.0 m in the cellar, on the ground floor and on the first floor. The results were as follows: at the floor level of 0.05 m – 27.4% (wet walls $U_m$ > 12%); 1.5 m – 17.4% (wet walls $U_m$ > 12%); 2.0 m – 11.6% (very damp walls $U_m$ 8-12%). Both the test results and the condition of the walls indicate high levels of dampness and salinity. Seventeen samples were tested to trace harmful salt contents. The presence of salts such as nitrates, sulphates and chlorides was determined. An analysis of the obtained results showed that the concentration of nitrates was at a low and medium level, while the concentrations of sulphates and chlorides were at a medium and high levels. Figure 1 shows the test results in the selected samples (Koda, 2017).

### 4.1.3. Description of research work performed in Szczytno

After examining the cellars, the presence of high levels of dampness in the underground walls and the lower parts of the external walls was noted. In order to obtain the precise data needed to determine the degree of dampness in partitions and stating which chemical compounds had entered the damp walls, samples of building materials were taken, the degree of dampness was measured and necessary measurements for determining the level of dampness were taken. Both the results of the measurements and the condition of the walls indicate a high level of dampness and salinity. The wall dampness amounted to 14%-19% (wet walls).

The floor was found to be very damp, as numerous stains indicated the intensive absorption of water through the floorboards. Six samples were taken to measure the content of harmful salts (nitrates, sulphates and chlorides). After analysing the test results, it was found that their concentrations were at medium and high levels. Figure 2 shows the test results in selected samples (Koda, 2005).




| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 50 cm | 0.61 | 4.08 | 0.15 | 0.12 | 0.5 | 0.11 | 0.05 | 0.24 | 3.1 |
| 150 cm | 0.6 | 4.01 | 0.1 | 0.1 | 0.47 | 0.09 | 0.04 | 0.22 | 3.01 |
| 200 cm | 0.52 | 3.75 | 0.05 | 0.09 | 0.4 | 0.04 | 0.03 | 0.18 | 2.59 |

**Fig. 2.** Concentration of salt in walls at the different measuring point heights (Szczytno)

## 5. Conclusions

This article addresses the problem of the damaging effect that external factors have on building partitions in historic buildings. The implementation of effective waterproofing in building construction is one of the most difficult and costly procedures. Implementing horizontal insulation in brick and stone walls in particular, adding vertical insulation where the access to the wall from the outside is limited, and adding insulation from the inside could be ineffective or even inadvisable.

The analysis of the degree of wall dampness and the presence of harmful salts in building materials lead to the conclusion that the following externals factors heavily contribute to damp problems in buildings:

- topography around the building;
- rainwater removal from the building;
- material and structure of a horizontal band around the building;
- presence of biologically active surfaces on the plot (e.g. lawns, trees, shrubs)
- building materials used in partitions;
- wall structure used in the building;
- extent and correctness of technical solutions adopted during renovation works, earlier alterations, modernisation and re-bricking of the building;
- use of appropriate construction materials for renovation works (with technical parameters appropriate for historic buildings);
- effective ventilation;
- watertightness of window and door joinery (as it has a significant impact on the effectiveness of gravity ventilation);
- method of performing cleaning works (e.g. floor cleaning).

The analysis of the test results of the samples taken in both buildings has shown large discrepancies in the salt concentration in the building partitions. The building in Białystok shows high concentrations of chloride and sulphate compounds. The building in Szczytno shows high concentrations of the chloride and sulphate compounds in only two samples. The other samples taken from the building partitions show low levels of concentrations of harmful salts.

Such large differences in the concentration of harmful compounds result from various building materials used in the construction of the walls and the immediate surroundings of the building. Along with the presence of high salt concentration in building materials, dampness of the walls occurs. This leads to the reduction of the insulating power of the walls, the destruction of their structure and the formation of cracks and scratches, which in turn, cause a rise in the absorption of moisture.

The differences in the test results depended on the following external factors:

- building material from which partitions were made;
- structure of walls in the building;
- immediate surroundings of the building, the type and material of the horizontal band around the building, and the area where the buildings are located;
- natural watercourses and the presence of lakes, rivers, rainwater catchments;
- level of ground water;
- ground and geological conditions;
- depth of foundation walls.

## References

Andreas, A. (1981). Nature and relations of salinenminerale in Wells. *The Conservation of Stone II, Preprints of the Contributions to the International Symposium*, Bologna.

Gosztyła, M., Pastor, P. (2013). *Konserwacja i ochrona zabytków architektury*, Rzeszów: Oficyna Wydawnicza Politechniki Rzeszowskiej.

Grabski, W., Nowak, J. (1957). Problem niszczenia się kamienia w budowlach zabytkowych Krakowa. *Materiały Budowlane*, no. 3, 72.

Ickiewicz, I., Koda, P. (2018). The influence of the environment on objects of historical value. *Journal of Civil Engineering, Environment and Architecture*, no. 35, 65.

Janowski, Z. (1999). Metody i materiały stosowane do napraw tradycyjnych konstrukcji murowych. *XIII Ogólnopolska Konferencja: Warsztat Pracy Projektanta Konstrukcji*, Ustroń.

Jasienko, J. (2003). Zasolenie i zawilgocenie murów ceglanych w obiektach zabytkowych – diagnostyka, metodyka badań, techniki rehabilitacji. *Wiadomości Konserwatorskie*, no. 14, 43–48.

Karyś, J. (2001). Korozja chemiczna i ektrochemiczna towarzyszące korozji biologicznej w obiektach budowlanych. In: J. Karyś (ed.), *Ochrona budynków przed korozją biologiczną* (pp. 200–206). Warszawa: Arkady.

Kęsy-Lewandowska, M. (1999). *Badania nad odsalaniem murów*. In: B. Soldenhof (ed.), *Konserwacja murów ceglanych, badania i praktyka* (p. 44). Toruń: Wyd. UMK.

Koda P. (2005). *Ekspertyza techniczno-mykologiczna o stanie zawilgocenia i zasolenia ścian budynku Sądu Rejonowego w Szczytnie*.

Koda, P. (2017). *Ekspertyza techniczno-mykologiczna o stanie zawilgocenia i zasolenia ścian budynku dawnej loży masońskiej w Białymstoku.*

Kozłowski, R., Olesiak, J. (2000). Wilgoć w budowlach zabytkowych. *Renowacje*, no. 4, 82–84.

Lyndsie, S. (2004). *Metal and Corrosion. A handbook for the Conservation Professional*, Canadian Conservation Institute.

Matkowski, Z., Pawlonka, A. (1982). *Analiza nieniszczących metod badania wilgotności betonu*, PhD Thesis, Wrocław: Politechnika Wrocławska.

Nawrot, W. Osuszanie budowli – metoda iniekcji krystaliczno-mikrofalowej. Renowacje, no. 4, 76–78.

Nurnberg, U. (2001). Corrosion of Metals in Contact with Mineral Building Materials. *Otto Graf Journal*, vol. 12, 69–80.

Weber, J. (2012). Baudiagnose und Geräte. In: *Bauwerksabdichtung in der Altbausanierung: Verfahren und juristische Betrachtungsweise* (pp. 99–135). Wiesbaden: Springer Vieweg.

Wesołowska, M. (2016). *Ochrona murów licowych przed wpływem środowiska*, Bydgoszcz: Wydawnictwo Uczelniane UTP.

Wójcik, R. (2004). Izolacje przeciwwodne przyziemia budynków. Metody chemiczne. *Izolacje*, 7–8.