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RENOVATION OF BUILDINGS HAVING DAMP AND SALTED WALLS – CASE ANALYSES

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ABSTRACT

This article discusses the issue of renovation of buildings having damp and salted walls. The results of conservation research on the walls of two historical buildings from the beginning of the 20th century are presented. It was determined that the walls of the buildings are burdened with moisture and salts. The use of traditional cement and limestone plaster for renovation of such walls, due to their low diffusivity, is a temporary and short-term solution. A suitable material is a renovation plaster, which should be selected depending on the properties of the wall. Various approaches to the renovation of these two buildings were presented. Where moisture was caused by capillary rise, the moisture barrier was first restored and a system of renovation plasters consisting of rough coat, undercoat plaster, hydrophobic plaster and paint coating was used. In the second case, due to only a partial replacement of the plasters, after protection of the facade against rainwater, the plasters will be supplemented with renovation rough coat and hydrophobic renovation plaster. Before applying the paint coating, the entire surface will be covered with a renovating lime putty.

Key words: renovation plasters, salts in walls, moisture in walls

INTRODUCTION

In the renovation of historic buildings having damp and salted walls, repetitive treatments leading to a permanent reduction in the level of moisture in the walls can be distinguished. The procedures are based on the sequence of operations: source identification → root cause removal → repair. Walls are considered dry if their mass humidity is at the level of 3–6%. The basic technological renovation activities are related to the restoration of horizontal and vertical damp proof insulation, solving the problem with salts, repairing the walls and refurbishing the facade elements to restore aesthetic value (Brachaczek, 2018a). Subsequent operations are performed to reduce the dampness of the walls. Limiting renovation work merely to a restoration of moisture barriers only does not guarantee that the walls will dry out. Walls with considerable thickness which are protected against water may dry out for many years under natural conditions. If the drying procedures are not carried out in an appropriate way, the damp wall containing salts will continue to be destroyed and degraded. While technologies for conducting renovation treatments are known and widely used, there is no single universal method which can be used for most historic buildings (Charola, 2000). The selection of comprehensive technological solutions leading to the reduction of the mass humidity of walls is still controversial. One method used for different buildings may sometimes bring different results. The reasons for this are manifold. The choice of a technological solution is influenced by many factors ranging from the degree of moisture or salts content to the workmanship. The reason may be restrictions

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related to the condition of the walls or the properties of the materials which they are made of. Modern repair materials happen to react with the wall substance, which leads to unexpected effects such as swelling or loosening. Further restrictions are related to the very method of performing renovation works. Often, the need to preserve original design solutions does not enable performing certain treatments effectively. In particular, these are the situations related to moisture protection of hard-to-reach places that, due to their unique nature, must be left intact. When drying walls, too rapid removal of moisture may sometimes cause damage to the substance of the walls and losing their strength due to the capillary forces in the pores.

The impact on the nature of the salt-induced damage to the walls depends on the materials and the exposure of the wall elements. Salts may be accumulated in dry walls for decades and only to a slight degree contribute to the damage. The damage is the most severe in damp walls. Salts are crystalline substances, easily soluble in water. The most dangerous salts include: sodium, potassium, magnesium and calcium chlorides, nitrates and sulphates. Nitrates occur in the external environment as products of biological oxidation of organic compounds or come from agricultural fertilizers. The sources of sulphates in urban areas are flue gases emitted by the combustion of hard coal and liquid fuels. The occurrence of chlorides can be associated with the use of de-icing agents for pavements and roadways. All of these salts can be found in groundwater (Lubelli, van Hees & Groot, 2006; Hall & Hoff, 2007).

The moisture problem applies to most historic buildings. The most common cause of penetration of walls by the salt is damage or lack of waterproofing protection of the walls against moisture from the side of the ground. In this case, salt transport is the result of capillary rise of solutions through the micropore system present in building materials (Gorecki & Wyrwał, 2010). It can be carried out by means of advection (salt transport), dispersion and diffusion (due to salt concentration gradient). As a result of the advection, salts and moisture are transported towards the outer surface. The transport by means of advection and dispersion occurs with considerable moisture content. Diffusion is a phenomenon competitive to the transport of salt by way of advection or dispersion. It occurs in higher parts of walls with lower humidity, when, as a result of evaporation, the moisture in the outer layer of the wall is successively enriched with a greater amount of salt ions in relation to the moisture inside the material. The salt ions will then move towards a lower concentration environment, i.e. opposite to the direction of drying (Petković, Huinink, Pel, Kopinga & van Hees, 2010). Under natural conditions, as a result of alternating damping and drying of walls, salts present in the pores undergo cyclic dissolution and crystallization. This results in the destruction of the wall structure due to the generated crystallization pressure affecting the pore walls of building materials (Brachaczek, 2018a).

Regardless of the way the salts enter the walls, they dissolve in contact with water. Due to their concentration, such solutions may be unsaturated or supersaturated. The supersaturated solution can be found in the porous structure of building materials if moisture together with the salts dissolved in it continuously penetrates into the walls, and then evaporates in the higher parts of the wall. As the moisture evaporates the salt concentration in the pores increases. This phenomenon is accompanied by an increase in the viscosity of the solution, and thus a reduction in the rate of moisture transport by way of advection. With the gradual increase in salt ion concentration, the solubility limit of the solution is exceeded. As a consequence, thermodynamically unstable supersaturated solutions are formed, spontaneously striving to transform into saturated solutions by precipitating excess substance in the form of crystals. As a result of the linear growth of crystals from the supersaturated solution, an increase in hydrostatic pressure is observed, which is due to the increase in the total volume of the crystals and the solution relative to the volume of supersaturated solution before crystallization. The hydrostatic and/or crystallization pressures generated in this way may exceed the tensile strength of the material, causing its destruction. As a result of this mechanism a degradation of plasters and walls in the moisture zone progresses, salt efflorescence occurs, plasters and paints peel off (Pavlíková, Pavlík, Keppert & Černý, 2011). In addition, the dampness of the walls affects the unfavourable microclimate of rooms, contributes to the infestation of the building by mould fungi or insects, which may result in health problems. It also reduces the thermal insulation of the wall.

The effectiveness of renovation works on buildings with salted and damp walls depends on proper diagnostics and cooperation of specialists qualified in specific fields (designers, contractors and technology providers). Partially, the principles of this process are described in the WTA 4-5-99/D instruction titled "Evaluation of masonry" (Wissenschaftlich-Technische Arbeitsgemeinschaft für Bauwerkserhaltung und Denkmalpflege e.V. [WTA], 1999). However, due to the complexity of the problem and the development of new technologies, this instruction can be a valuable guideline and needs to be combined with professional and specialized knowledge. To renovate historic buildings, it is necessary to recognize the nature and properties of the materials used. After detailed testing, materials working well with the original material and thus facilitating the repair are selected. Determination of the degree of saltiness and dampness of walls is only one of the necessary tests (Bajno & Budnik, 2019). In addition to these, it is also important to determine other properties, such as the strength of the original materials, sorption coefficient, density, microstructure of pores, bricks and joints. The development of technologies and materials for the renovation of historic buildings with salted and damp walls was especially pronounced in restoring moisture barriers. The choice of a way of restoration of horizontal insulation depends on the structure of the walls, their thickness and, above all, their condition (Brachaczek, 2018b). The buildings have often been rebuilt many times over the centuries, and they have been modernized and renovated according to the knowledge and technology corresponding to the given era. Cracks and crevices often occur in historical walls, and also affects the selection of the appropriate method. Due to the thickness of the walls, the chemical injection method is often used to reconstruct moisture barriers. Despite the fact that the modern building materials enable carrying out works so as to prevent further destruction of the walls, a number of mistakes are made during the works. Errors can be made at any stage of renovation, resulting in negative opinions about the innovative technological solution or innovative repair materials. An example would be mistakes made during reconstruction of horizontal moisture barriers by injection. It happens that injections are performed improperly in cracked walls containing voids without pre-injection. The pre-injection consists in pre-filling holes with sealing mortar, whose task is to fill gaps and voids in the wall. Another mistake is making injections in stone walls. Holes are often drilled in stones with low absorbency, while moisture as a result of capillary rise moves in the joints. In such cases the injection is ineffective because the injected filler cannot penetrate the wall. Another factor affecting the durability of renovation works is the inadequate way of conducting plastering works. Occasionally, after restoring moisture barriers, plastering works are carried out using traditional lime and cement mortars. In most cases, such mortars not only limit drying walls due to low diffusion relative to water vapour, but they can also contribute to a serious deterioration of the historic walls due to the mismatching of plasters to the substrate. Such situations occur in particular during renovation. In these cases, the wall is highly varied in terms of strength and has different water absorption. Fresh, thin mortar applied to old walls will dry quickly. Also the hydration of cement proceeds quickly, which may result in a significant shrinkage. This is when the mismatch between the plaster and the substrate becomes evident. Restricting the freedom of deformation for these materials generates high tensile stresses in the plaster layer. However, if the plaster yield point is exceeded, it will crack. In broad outline, it can therefore be pointed out that the shrinkage of plaster layers on the rigid substrate would be the direct cause of cracks in a direction normal to the substrate. Most traditional plastering mortars are characterized by high drying shrinkage and low flexibility which makes them completely useless in renovation works, and their use is even harmful to walls. Special plaster mixtures modified with plasticizing admixtures (polymers) are suitable for such substrates. Admixtures based on natural and artificial polymers are of particular importance here. The improvement is in the amount of shrinkage, flexibility and adhesion to the substrate and aggregates, water retention, etc. The addition of polymer modifiers to cement mixes improves flexibility of the plasters. As a result, their susceptibility to shrinkage cracks is reduced. The most suitable material for carrying out plastering works on salted and damp walls are renovation plasters.

Renovation plasters are intended for damp and salted walls. These are porous plasters characterized by high resistance to salt. Most manufacturers do not offer only a single product but several mortars constituting a renovation plaster system. Such a system includes: renovation rough coat, renovation undercoat plaster, hydrophobic renovation plaster, renovation putty and paint coating. The properties required for such plasters are included in the PN-EN 998-1:2016-12 standard titled "Specification for mortars for masonry. Part 1: Plastering mortar" (Polski Komitet Normalizacyjny [PKN], 2016). In the standard, only the properties of hydrophobic renovation plaster for damp and salted walls are specified. The issue of renovation plasters is more widely addressed in the WTA 2-9-04/D instruction titled "Renovation mortar systems" (WTA, 2004). This document does not refer to a single product, but to a renovation plaster system whose components have the right properties and are compatible with each other. Although renovation plaster systems have been used for several decades, and in many cases the benefits of using them are obvious, there were also some critical opinions. The reservations concerned the adverse impact on wall structure. In some cases, it has been observed that damp walls covered with renovation plasters tend to retain moisture what resulted in the plaster peeling off in winter. As a consequence, historic building conservators have increasingly refrained from using renovation plasters. In some European countries, administrative authorities responsible for the protection of cultural heritage began to prohibit the use of these materials on historic buildings. In Poland, the main problems which contractors face are related to the appearance of salt efflorescence, the appearance of scratches and cracks, low cohesion, difficulties with application and processing. Although the problems of using renovation plasters is a topic of constant discussion, it can be concluded that the reasons for these shortcomings can be seen in the inadequate matching of renovation technology and materials to the properties of the restored walls.

This paper presents different approaches to renovation of two buildings from a similar period. Both buildings come from the beginning of the 20th century. They were built on a site where originally one--storey buildings, probably from the turn of the 18th and 19th centuries, were located. In both cases, renovation plasters were used for restoration. However, due to the varying salt and moisture contents in these buildings, different approaches to renovation were presented.

MATERIAL AND METHODS

Study objects

The first building – called the Under the Frogs – is a tenement house at 12 Wojska Polskiego Square in Bielsko-Biała. The tenement house was built in the Art Nouveau style, and, in addition to the apartments, once housed a well-known winery of Rudolf Nahowski. The house has an irregular shape piled up at the corner into a high tower. The top floors are decorated with imitation of half-timbered wall made of plaster. The half-timbered wall decoration is also visible on the level of the third floor on the facade from the side of the Wojska Polskiego Square. At the top of the roof, a forged structure with fancifully curled elements, to which winery advertising was attached, was preserved. Windows with various patterns were arranged asymmetrically. The northern wall is decorated with a portal crowned with figurines of two frogs of which one holds a mandolin and the other a long pipe in one hand and a wine glass in the other, resting its elbow on a barrel, most probably full of wine (Fig. 1).

The second building is located at 2 Waryńskiego Street. It is characterized by a traditional layout of the block derived from the neoclassical pattern. It consists of a massive rusticated plinth covering the ground floor. The building has refined flat facades, crowned with a line of strongly shading prominent eaves cornice, supported on stone brackets. The walls stand out with their delicate ornamentation of window frames in the form of wreaths, which makes the whole structure seem light. The ground floor with rectangular windows creates an oblong-shaped plinth with elongated rustications. Higher floors with windows framed in plaster, arranged symmetrically along with the portal constituting the entrance door frame enhance the impression of orderliness and peace.

Fig. 1. The front wall of the "Under the Frogs" house at Wojska Polskiego Square (on the left), tenement house at 2 Waryńskiego Street (on the right) in Bielsko-Biała

Under the eaves, there are wreath-shaped decorations. The neoclassical roof with a slight inclination contributes also to lightness of the building, which makes it stand out among other tenements. The north-eastern facade of the building with a wooden floor balcony and a forged iron railing and brackets closes a string of tenement houses built on the embankment. Above the roof covered with steel sheet there are huge brick chimneys covered with plaster, while the walls above the ground are made entirely of full brick. The building has a partial basement. The floors of the non-basement part are made of concrete on bedding. The basement walls are made of bricks and natural stone and are covered from the inside with cement and lime plaster. The ground floor is vaulted, the upper floors are covered with faceted beam ceilings with sound boarding. Inside the building there is a prominent staircase with block steps mounted to the stringers and the staircase wall. The first and second floor plasters were made of lime mortar. The original rustication at the ground floor level and the inter-story cornice above the ground floor are made of strong, dark beige mortar in the dark sandstone colour. In the places where capillary rise occurred, as a result of previous renovation works, the plasters were replaced with cement and cement-lime plasters. Stucco details were either made of lime mortar or were plaster casts. They were covered with a layer of lime gesso. Inside the building there are stone plinths of white marble.

Measurements

Diagnostic examinations of the walls included visual inspection of the facade as well as determining the level of moisture and salt saturation of the walls at the external facade and basement walls. Moisture testing of the masonry was performed using a non-invasive method, using Protimeter Surveymaster and Trotec T3000 hygrometers. For this purpose, holes were drilled at heights of 10, 50, 100 and 150 cm from ground level, to a depth of approx. 10 cm. When determining the vertical lines in which the measurements were read, equal distances between them were kept. These lines were routed so as to avoid obstacles.

The level of concentration of harmful salts was determined based on samples of plasters, bricks and mortars taken from the central part of the walls on each side of the building using a low-speed drill. In particular, wall sections degraded to the greatest extent were examined. The concentration of chlorides, sulphates and nitrates was analysed. The tests were carried out in accordance with the guidelines of the WTA 2-9-04/D instruction. The tests on the samples were carried out in the laboratory of Sempre Farby company.

RESULTS AND DISCUSSION

Moisture and salt content

To determine the degree of moisture, the classification for brick walls in accordance with PN-EN ISO 12570:2002 standard (PKN, 2002) was used. The measurement results are presented in Tables 1–3. According to WTA 4-5-99/D in terms of the dampness of the walls, the following division is applied: a wall with

Table 1. The results of moisture content in walls by weight [%] for the house at 2 Waryńskiego Street

Measurement height [cm]	Front wall (south-east)								
	1	2	3	4	5	6	7	8	9
150	14.4	12.6	2.4	2.4	2.6	1.5	11.1	4.3	3.1
100	12	22	11.2	10.9	4.8	4	5	4	3.1
50	10.6	17.2	16.3	9.3	5.5	6	8	14	5.5
0–10	5.5	18.6	13.6	15.9	22	22	16.2	17	3

dry wall; wall with increased humidity; wall with an average humidity; very humid wall; wet wall

Table 2. The results of moisture content in walls by weight [%] for the house at 2 Waryńskiego Street

Measurement height [cm]	Sidewall (north-east)		Rear wall (north-west)				
	1	2	1	2	3	4	5
150	3.4	16.6	10.7	17.8	4.4	18.7	22
100	5.5	4.6	22	9.9	14	5.5	5.8
50	3.8	4.2	9.9	11.3	18.3	3.1	22
0–10	3.6	19.8	13.9	22.0	8.8	19.0	5.7

wall with increased humidity; wall with an average humidity; very humid wall; wet wall

Table 3. The results of moisture content in walls by weight [%] for the house at 2 Wojska Polskiego Square

Measurement height [cm]	from Wojska Polskiego Square			from 2 Targowa Street			
	1	2	3	1	2	3	4
150	1.6	1.7	12.3	1.8	1.6	1.6	5.5
100	3.5	1.7	3.5	1.8	1.8	1.6	1.8
50	2.1	2.5	1.7	8.9	1.9	1.6	1.7

dry wall; wall with increased humidity; wall with an average humidity; very humid wall an acceptable mass humidity not exceeding 3%, a wall with increased humidity with humidity of 3–5%, a wall with an average humidity of 5–8%, very humid 8–12% and wet with mass moisture above 12%.

The measurement results of the salt content are presented in Tables 4–5. To determine the degree of the salt content, the classification for brick walls in accordance with the WTA 2-9-04/D instruction was used. According to this classification the following division is used in respect of the salinity of the walls: a wall with a low salt content, a wall with a moderate salt, and a wall with the high salt content.

Based on the testing and examinations carried out, it can be concluded that the facades of both buildings are in very poor condition. In the case of the "Under the Frogs" tenement house, the plinth of the building made of stone is badly damaged (Fig. 2). A direct cause of plinth damage was splashing rainwater from the street, snow and ice accumulating in this part of the wall, as well as the effects of defrosting agents. Building facades from the side of Targowa Street were renovated in the 1990s. The facade from the side of Wojska Polskiego Square was renovated several times, as it was determined based on the stratigraphic studies.

The building's facades are in very poor condition, both in terms of technology and aesthetics (Fig. 3). Roof eaves, cornices under and over the windows are secured with flashings or plain tiles. Flashings are damaged, cracked, deformed, and do not fulfil their protective function. Lack of protection against water caused the mortar to be washed out, loosening strong compact parts of stucco elements. There are numerous defects on the surface of the cornices, moreover there are surface peels, stains, salting, cracks, biological corrosion. Penetrating and freezing water caused deep cracks and peeling off from the surface, individual loose elements fell off.

Table 4. Averaged salt content of the walls of the tenement house at 2 Waryńskiego Street

Ion type	Measurement of salt content and limit values for individual loads by weight [%]					
	north-western wall	north-eastern wall	south-eastern wall	loading with salts – limit values acc. to the WTA 2-9-04/D		
				low	moderate	high
Chlorides (Cl^-)	0	0	0.5	< 0.2	0.2–0.5	> 0.5
Sulphates (SO_4^{2-})	0.2	0.8	0.8	< 0.5	0.5–1.5	> 1.5
Nitrates (NO_3^-)	0.025	0.125	0.125	< 0.1	0.1–0.3	> 0.3

wall with a low salt content | wall with a moderate salt content | wall with the high salt content

Table 5. Averaged salt content of the walls of the tenement house at Wojska Polskiego Square

Ion type	Measurement of salt content and limit values for individual loads by weight [%]				
	the wall from the Wojska Polskiego Square	the wall from the Targowa Street	salts content – limit values acc. to the WTA 2-9-04/D		
			low	moderate	high
Chlorides (Cl^-)	0	0	< 0.2	0.2–0.5	> 0.5
Sulphates (SO_4^{2-})	0.6	0.4	< 0.5	0.5–1.5	>1.5
Nitrates (NO_3^-)	0.025	0.25	< 0.1	0.1–0.3	> 0.3

wall with a low salt content | wall with a moderate salt content | wall with the high salt content

Fig. 2. Details of the facade of the "Under the Frog" tenement house at the Wojska Polskiego Square in Bielsko-Biała

Fig. 3. Damage to the facade resulting from the impact of rainwater in the "Under the Frogs" tenement house in Bielsko-Biała

The destruction of plasters is so great that whole fragments of the stucco peeled and fell off. Some stucco elements made of thickly applied mortar are connected to the wall with nails and there is a risk that they could fall off. Damage caused by water and snow on cornices and the lack of a hydrophobic coating on the surface of the walls caused water to be absorbed into the plaster and brickwork joints. On the surface of the plasters, stains, moisture, water-soluble salts in the form of efflorescence are visible above the treatments, plasters are disintegrated, cracked, detached, sanded, with especially severe changes in the lower parts of window bands. Original lime plasters are heavily weathered and form a crust. In many places they have become detached from the wall. The main factors causing damage were: rainwater flowing down the facade with no flashings, water coming from capillary rise and atmospheric pollution.

Analysing the results of humidity tests presented in Table 3, it can be concluded that the moisture level of the walls building is very uneven. No decrease in the mass humidity correlated with the height of the wall was observed. Therefore, it can be assumed that capillary rise from the foundations side in the walls is insignificant. With so little moisture, there is no need to restore the horizontal moisture barrier. However, the destructive effects of water can be observed on the building's facade. The humidity level is high in some places. It can therefore be expected that in certain places, as a result of flooding the facade with rainwater, the water content in the walls can be high. When testing the walls for moisture content from the inside, the humidity of the walls did not exceed 3% by weight.

Analysing the research results of the degree of the salt content in the walls presented in Table 5, the presence of nitrate and sulphates ions corresponding at low to medium content were found. However, no chlorides were found in the walls. Despite the fact that the building's walls are in the immediate vicinity of the paved streets, the walls were not loaded with chlorides. It should be noted that the plinth of the building was covered with natural stone cladding which could protect the walls against the effects of salts used for de-icing. Based on the examination, it can be concluded that the stone cladding suffered the most due to the influence of external factors, however, proved to be an effective protection for this part of the walls.

In case of the building at 2 Waryńskiego Street, humidity tests presented in Tables 1 and 2 indicated that the mass humidity distribution in the walls was high. A clear trend of the humidity level decrease along with the height of the measurement can be observed on all walls. This indicates the capillary rise of moisture in the wall and is the result of damaged horizontal insulation of the building walls or lack thereof. Moisture is pulled up from the ground by old bricks and mortar within a capillary system. In addition, an increase in humidity in the lower, unsecured vertical insulation zone (up to approx. 50 cm above ground level) may come from splashing rainwater. Also, the greatest damage in this building was observed in the bottom part of the plinth and in all places where the flashings were significantly damaged and ceased to fulfil their function (Fig. 4).

Analysing the results of salt content in the walls presented in Table 4, the presence of chloride, sulphate and nitride ions corresponding to medium content were found. The highest nitrate concentration was found in the front wall directly adjacent to the street. It was also here that the concentration of chloride and sulphates was the highest.

Technology and materials used in renovation works

In the case of the "Under the Frogs" tenement house, the first scope of renovation works involved inhibiting the destructive factors. To this end, in the first stage of work it is necessary to cut off the supply of water, both pulled up by capillary rise and flooding facades due to damaged and missing treatments. Fitting the missing tiles and reinstalling them in places where they protected cornices. In the next stage, removal of all secondary elements such as cables, advertisements, antennas being the source of local moisture penetration into the walls. The stone pedestal was cleaned of efflorescence and cement wash – manually or mechanically using chisels, hammers and scrapers. All joints were also removed. The stone defects were filled with sealing compound, the joints were filled with grouting mortar containing trass. The whole structure was protected with a water-repellent Sempre Aqua protekt preparation based on silicone microemulsion. To reconstruct the stucco details, the Renowator 740 composite stucco mortar (Sempre) was used.

Since the tenement house is a peculiar piece of architecture of exceptional historic value, the next stage of the renovation will consist in emergency preservation of the facade. The removal of wet, loosened and detached plasters has been foreseen. It is planned to remove simple plasters in 50%, stucco details in over 30%. The plaster whose condition does not allow structural strengthening and gluing will be removed.

Fig. 4. House at 2 Waryńskiego Street, the figure shows the destruction of the walls caused by ground water rise

Well-preserved primary plasters and stucco elements will be reinforced with a reinforcing preparation based on silicone resins, silicates or fine-molecule silicates (tetraethyl silicates), e.g. Renowator 350 by Sempre Farby. As no capillary rise of groundwater from the foundations was found, the restoration of the horizontal moisture barrier was not performed. However, due to the partial moisture penetration in the walls, it was decided to replace the removed plasters with Renowator 545 – hydrophobic renovation plaster for diffusion plaster rendering. Application of the plaster will be preceded by proper preparation of the substrate, consisting in cleaning the wall of dust, dirt and grease. In order to avoid cracks and discoloration on the surface of the plaster coat, the brittle and weathered joints between the bricks will be removed to a depth of 2 cm. Places covered with mosses and algae will be cleaned with steel brushes and then disinfected with Aglesil algae remover. In order to reduce the water absorption before application of the rough coat, the surface will be wetted with water. The first plastering layer will be made of the Renowator 500 renovation coat, which will improve the adhesion of the next layer of renovation plaster to the substrate. Unification of the facade surface, especially in the places where primary plasters and renovation plasters are combined, will be made using Renowator 680 renovation lime coat. The protective layer will be silicone paint with reduced dirt adhesion and self-cleaning capabilities (e.g. Sempre Azzuro).

In the case of the building at 2 Waryńskiego Street, the first scope of renovation work included roof repair combined with the replacement of roof slopes with window joinery renovation, replacement of flashings together with rainwater drainage system. In order to protect the building against the harmful effects of water coming from the ground, it is planned to restore the horizontal moisture barrier by injection. Due to the specific nature of this method, a waterproofing horizontal insulation just above the ground level was planned for all analysed walls, except for possible pressurized water impact. This will protect the building parts above the ground against moisture migrating from the ground. The varied nature of the foundations, mostly made of stone, and the voids or gaps occurring in it, determined the use of low-pressure injection combined with pre-injection to restore horizontal insulation. The pre-injection consists in pre-filling holes with sealing mortar, whose task is to fill gaps and voids in the wall. Optionally, in the case of stone and brick walls with a diverse structure, good effects are obtained by using gravity injection with an agent of high consistence. This product contains polysilicate compounds, well penetrating building materials. They form a tight moisture barrier as a result of a change in surface tension of the pores. The advantage of this product is high consistence which facilitates application in walls of high heterogeneity. In order to eliminate the impact of splashing rainwater on the humidity of the walls, it was recommended to secure the plinth zone of the walls (at a height of up to 50 cm) with vertical sealing mortar.

Due to the considerable destruction of plasters, it was necessary to remove them down to the brick layer. Most of the walls were in good condition, however they were very wet and salted. The condition of the bricks was very diverse, with some of them strong, and others weak and brittle. The mortar which the joints were made of was largely rotten and brittle. At some windows, especially in the upper floors of the southern facade, cracks of cornices and bands around the windows could be observed. Due to the high saltiness and dampness of the walls, higher than in the case of the “Under the Frogs” tenement house, the use of traditional cement and lime or cement plasters for renovation would be a temporary solution. Due to the low diffusivity of water vapour, on damp and salted walls, such mortars tend to peel away and crack. This phenomenon may be affected by such factors as stress caused by salt crystallization, as well as mismatching of plaster properties to the substrate. According to Brachaczek (2018b), a single type of renovation plaster with universal properties should not be used to renovate historic buildings. There is probably no such plaster available anyway. The walls differ in water sorption coefficient, strength, diffusion resistance, etc. Whenever choosing plasters, their compatibility with the substrate needs to be checked. Damp walls with a low water sorption coefficient should not be covered directly with hydrophobic plasters. The low sorption coefficient of the walls means that the walls dry slowly and the water is stored in them for several years. In such cases, only renovation plasters with high water sorption properties may be used for renovation. In order to avoid the appearance of scratches and cracks resulting from mismatching the plaster strength to the substrate, additional compressive and bending strength tests as well as sorption tests were carried out in accordance with PN-EN 1015-18:2003, PN-EN 12390-3:2019-07 and PN-EN 12390-5:2019-08 standards (PKN, 2003, 2019a, 2019b). Six brick samples were taken from each side of the building. The averaged results are summarized in Table 6.

Table 6. Physical properties of the tested brick

Tested brick property	Value
Absorption coefficient [$kg \cdot m^{-2} \cdot min^{-0.5}$]	0.26
Compressive strength [MPa]	5.80
Tensile strength [MPa]	1.79

According to the WTA 2-9-04/D instruction, the effectiveness of plasters in wall drying depends on appropriate porosity (> 60%) and distribution of pores (the number of capillary and air pores), enabling the capillary transport of moisture, diffusivity ($m < 10$), surface absorption coefficient $w > 1\ kg \cdot m^{-2} \cdot h^{-0.5}$.

The plastering was preceded by preparatory works consisting in removing fragile and weathered joints to a depth of 2 cm and supplementing them with fine-grain Renowator 520 renovation undercoat plaster. The building walls were covered with a system of renovation plasters with layer thicknesses determined on the basis of the WTA 2-9-04 instruction. The wall bonding layer was made using a renovation rough coat, which should cover the wall in an openwork pattern, i.e. on 50% of the wall surface, and its thickness should not exceed 0.5 mm. The next layer was made of Renowator 520 undercoating plaster. The main function of this layer is to store salt. It is characterized by high porosity, high vapour permeability and high water sorption coefficient. The thickness of this layer should be between 1–2 cm. Directly on it, Renowator 540 hydrophobic, vapour-permeable renovation plaster was applied. It accumulates salts to a lesser extent than the undercoat plaster, prevents salt from getting outside the plaster coat. The thickness of this layer should be 1–2 cm. In order to obtain a smooth, aesthetic surface, the facade was covered with a fine-grained vapour-permeable finishing layer of Renowator 580.

The proper function of renovation plasters is possible due to the creation of a suction force causing the moisture to transfer from the wall to the plaster placed on the wall. This is possible when the plaster water sorption coefficient is greater than the one of the brick. In this case, for the analysed wall materials, the suitable plaster is Renovator 520 undercoat renovation plaster. The sorption coefficient of this plaster is high and it is greater than the determined wall sorption coefficient of $0.3\ kg \cdot m^{-2} \cdot min^{-0.5}$. Strengths of renovation rough coat, porous and hydrophobic plaster are 4.4, 3.8 and 3.4 MPa, respectively. They correspond to CSII class plasters with a strength of 1–5 MPa. Compared to the bricks encountered in the building, these plasters have the lowest strength and should not have a destructive effect on the structure of the walls. This is very important, because in the case of plaster with strength clearly higher than the material to which it is applied, there is a risk of shrinkage leading to the destruction of the top layer of the brick. Moreover, renovation plasters containing polymer modifiers have been used for renovation, reducing shrinkage during drying, improving plaster elasticity, adhesion to the substrate and water retention.

Damaged stucco elements were restored using Renowator 740 stucco mortar. It is characterized by excellent workability, low shrinkage when drying and resistance to weather conditions. In order to insulate the vertical plinth zone of the building, the lower part of the building (up to 50 cm above the ground) was cleaned of old plastering down to the brick layer, and then covered with Renowator 300 – two-component, highly elastic sealing compound. It protects the covered wall against both moisture and rainwater as well as water penetration.

Evaluation of renovation works

There is a great deal of evidence acknowledging the effectiveness of renovation plasters used for renovating damp walls. The justification of the proposed solutions are multiannual observations of the renovated

Fig. 5. House at Wojska Polskiego Square (on the left), tenement house at 2 Waryńskiego Street (on the right) in Bielsko--Biała after renovation

buildings and the analysis of the cases described in the literature (Dudás & Terjék, 2015; Misiewicz, 2016). Figure 5 shows the state of elevation at Waryńskiego Street three years after renovation and the elevation of the building called Under the Frogs after a year.

In case of the tenement house at Waryńskiego Street, the dampness of lower than 3% was obtained after three years from renovation. The appointed time is consistent with the results achieved by (Gosztyła, Leś & Sikorski, 2017) in case of the tenement house at the main square in Rzeszów, where renovation plasters were also applied for renovating damp walls. The qualities of the plasters are frequently overestimated. One cannot expect renovation plasters to be effective if the source of dampness has not been removed. In such cases the plasters lose their properties as a result of storing more salt caused by capillary suction, which considerably shorter their durability (Dudás & Terjék, 2015). It is bad practice of some contactors to apply renovation plasters in the dampest spots, as well as to combine them with lime-cement of low permeability of water vapour. In this case the wall still remains damp and the dampness in the lime-cement area may be many times higher (Misiewicz, 2016). Another mistake is too much filling and smoothing, which considerably lowers the permeability of water vapour. Is also unacceptable to fill the corroded plaster by using materials of different characteristics than the existing plaster. It is not allowed to apply materials of low permeability of water vapour, for instance cement finish (Hughes et al., 2012).

SUMMARY AND CONCLUSIONS

Historic buildings are extremely valuable testimony to our culture and their renovation should be approached very individually. Before starting work, as much information as possible about the building needs to be gathered. Successful renovation must be preceded by a series of tests to determine the degree and source of moisture and saltiness. It is also important to examine additional properties of the wall (such as sorption or strength). Only on the basis of these properties renovation plasters can be selected so as to prevent water retention in the walls and the destruction of the substance which they are made of. The material solutions proposed in the study are optimal for the analysed wall. In each case, however, the same materials were used according to a different technology. Application of hydrophobic renovation plaster without the priming layer of salt-accumulating plaster to a wall with significant humidity and high load, may hinder drying the wall. In this case, when the water dries and evaporates, the salts will crystallize and accumulate in the narrow contact area between the renovation plaster and the wall. The pores constituting a sort of "ventilation system" will be narrowed and the hydrophobic nature of the pores will limit the transport of liquid water towards the outer surface of the plaster (tenement house at Waryńskiego Street). On the other hand, at low and medium moisture levels, coming mainly from rainwater, the use of just the renovation plaster is a good solution. The walls of the building will be protected against moisture penetration, especially if they only need to be applied to a part of the walls. The renovation carried out in this way will protect the building against the harmful effects of external factors and will increase its aesthetic value and comfort of use. It will also preserve historically significant elements of the wall, such as decorative details.

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RENOWACJE BUDYNKÓW Z ZAWILGOCONYMI I ZASOLONYMI MURAMI – ANALIZA PRZYPADKÓW

STRESZCZENIE

W artykule omówiono zagadnienie renowacji budynków z zawilgoconymi i zasolonymi murami. Przedstawiono wyniki badań konserwatorskich murów dwóch budynków historycznych pochodzących z początków XX w. Ustalono, że mury budynków są obciążone wilgocią i solami. Używanie do renowacji takich murów tradycyjnych tynków wapienno-cementowych czy cementowych jest rozwiązaniem doraźnym i krótkotrwałym ze względu na ich niską dyfuzyjność. Odpowiednim materiałem są tynki renowacyjne, które powinny być dobierane w zależności od właściwości muru. Przedstawiono różne podejścia do renowacji tych dwóch budynków. Tam, gdzie wilgoć spowodowana była podciąganiem kapilarnym, najpierw odtworzono barierę przeciwwilgociową oraz zastosowano system tynków renowacyjnych w układzie obrzutka, tynk podkładowy, tynk hydrofobowy, powłoka malarska. W drugim przypadku, ze względu na częściową tylko wymianę tynków, po zabezpieczeniu elewacji przed wodami opadowymi tynki uzupełnione zostaną obrzutką renowacyjną i hydrofobowym tynkiem renowacyjnym. Przed nałożeniem powłoki malarskiej całość powierzchni pokryta zostanie renowacyjną szpachlą wapienną.

Słowa kluczowe: tynki renowacyjne, sole w murach, wilgoć w murach