



Microstructure of renovation plasters and their resistance to salt

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HIGHLIGHTS

- Durability of renovation plasters.
- The resistance to salt crystallization.
- Intensity of salts solutions.
- Destructive effects of salts solutions.
- Plasters with low porosity and monomodal pore size distribution.

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ABSTRACT

One of the most important factors which decide about the durability of the renovation plasters is the resistance to crystallization of salt which dissolves under the influence of moisture. This paper demonstrates the results of the research on the influence of the microstructure of pores in cement-lime mortars and their resistance to various cyclical salts. Six plasters differing in porosity and microstructure were selected for the study. The purpose of the study was to alternatively soak samples with three solutions of salts: NaCl at a concentration of 25.9%, Na₂SO₄ at 18.3% and NaNO₃ at 45%, and then crystallize the salts. It was found that salts solutions have a various intensity of destructive effect on renovation plasters. It was demonstrated that the durability of plasters depends to a greater extent on the pore size distribution than on the total porosity *P_c*. Salts solutions do not have a destructive effect on plasters with a large variety of pores, whereas plasters with low porosity and monomodal pore size distribution were destroyed under the influence of Na₂SO₄ and NaNO₃ solutions. Porosimetry and electron microscopy were used in the studies.

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1. Introduction

The main factors that reduce the durability of the walls are the simultaneous impact of salt solutions and moisture [1]. In case buildings with damaged horizontal damp insulation, there may be a vertical flow of moisture from the groundwater up through the permeable wall structure. This type of moisture transport occurs as a result of capillarity and is the main source of walls salting. Under natural conditions, as a result of alternating dampening and drying of walls, salts present in the pores undergo cyclic crystallization and dissolution [2]. As a result of the nucleation of salt crystals, as well as further crystal growth, considerable tensile stresses are generated inside the walls, which can lead to serious damage [2]. The substrate type, including the structure of the pore system in the building material from which the walls are made, has a significant influence on this phenomenon [2–4]. The proper

selection of plasters is crucial in the renovation of damp and salted walls. Hence, renovation plasters are a good solution [5–7]. In contrast to traditional lime or cement-lime plasters, renovation plasters are characterized by high porosity. Thanks to their porous structure, the renovation plasters can extract salts from the walls, and at the same time provide space for accumulation of crystallized salts without being destroyed [8]. The pore size affects the durability of plasters and their ability to dry walls and accumulate salt. The pores in the plaster affect the transport of moisture with varying intensity. In most of the building materials, pores with a diameter from 0.1 to 70 μm are capillary active [9–11]. The pores with a diameter of more than 70 μm are not capillary active anymore. They have the ability to interrupt capillary pull of water and are called air pores, which can only be filled with pressurized water [12]. Pores with a diameter below 0.01 μm, are called gel pores, through which moisture does not flow, and they remain only filled with moisture [13]. Nucleation of salt crystals occurs in pores of various sizes. According to Wellman and Wilson [14], in pores

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with a diameter of less than 0.01 μm , there are lower flow rates of salt solutions, which cause the residence time of ions in these pores to be long and sufficient for the nucleation of crystals. According to Fitzner and Sneathlager [13], in case of a microstructure with polymodal pore size distribution in which the pores of different sizes are interconnected, crystal growth occurs in larger pores, where lower crystallization resistance occurs. In such a microstructure, the salt ions are sucked out of pores of smaller diameter, which prevents the nucleation of crystals in the pores of smaller diameter. According to Schaffer [15], greater damages due to crystallization occur in materials with a well-developed structure of micropores for which pores are lower than 2 nm, as compared to materials with larger pores size. In these pores, one can expect the greatest stresses associated with the crystallization of salt. According to Punuru et al. [16], materials containing pores with a diameter of less than 0.05 μm are less stable in terms of salt crystallization than others, with larger pores diameter. In pores with a larger diameter, in equilibrium conditions, sufficient space is provided for crystal growth to occur without generating harmful stresses [17]. According to Rembiś [18], materials with a wide range of pore sizes were much more resistant than those with a narrow size range of small diameter pores. In addition to the pore microstructure, the type of salt and, first of all, such properties as solubility, chemical activity, etc. influence the crystallization pressure. According to Espinosa [19], the circumferential tensile stresses present in the pores are varied and depend on the pore diameter, type of salt, the degree of solution supersaturation, the crystal contact surface and the surface of individual pores.

Although renovation plasters have been used for several decades, and in many cases the benefits of using them are obvious, there are also critical opinions. In many cases, it turned out that using them caused water to be retained in the walls and their drying was impaired. For significantly salted walls, some renovation plasters were unstable and had a tendency to detach and crack. Initially, it was thought that the causes of the problems were related to workmanship errors and were not taken too seriously. After conducting detailed analyses, it was found that the issues were caused by renovation plasters properties [20–23].

The article presents the results of investigations on the impact of plaster microstructure on cracking and crushing caused by various salt solutions. The crystallized salts in the plasters were studied by the means of Carlo Erba 4000 Mercury Porosimeter, and Jeol scanning electron microscope equipped with an energy dispersion spectrometer (EDS).

2. The aim of the study and research methodology used

The purpose of the study was to establish the relationship between the microstructure of renovation plasters and resistance

to the destructive impact of salt solution. The tests were carried out on plasters with different pore microstructure. The plaster's resistance to salt was determined by assessing the samples after cycles of soaking and drying in salt solutions and drying. For samples that were not destroyed after 70 cycles of salt crystallization, the testing was conducted by changing the compressive strength R_c [MPa].

2.1. Subject of the study

Six plasters with the compositions specified in Table 1 (identified with symbols from S1 to S6) were selected for the study. Three samples in each series (from S1 to S6), in the form of cubes with dimensions 5 × 5 × 5 cm, were prepared for the study. The conditions of sample curing and the method of their preparation were in accordance with PN-EN 1015-11:2001 [20]. Samples were stored in molds for first two days, and then for 5 days at 95% humidity and for 21 days at 65% relative humidity at the temperature of 25°.

The microstructure of the plasters was shaped by using two aeration admixtures in their recipe: admixture 1 based on sodium α -olefin sulfonate C_{14-16} and admixture 2 based on sodium lauryl sulfate (SLS) which enable obtaining pores of various sizes and perlite. The admixture 1 caused the formation of pores with diameters ranging from a few to several dozen μm , whereas the admixture 2 pores with a radius of several dozen to several hundred micrometers. The change in the amount of these admixtures affected total porosity and pore size distribution as intended. The porosity of individual plasters and the porosity structure are shown in Table 2.

2.2. Methodology of study

The study of corrosion resistance involved alternating soaking of samples with three solutions of salts: NaCl at a concentration of 25.9%, Na_2SO_4 at 18.3% and NaNO_3 at 45%. The ASTM Standard C88 - 71a [21] procedure with minor changes in terms of temperatures, sample size, salt concentration and exposure time in each cycle, was used to measure plaster immunity to salt aeration. The study was carried out in such a way that the hardened plaster samples were completely immersed in a salt solution at 20 °C for 2 h, and then removed and dried in a laboratory drier at 50 °C for a period of 20 h. Before next soaking, the samples were cooled down to 20 °C for two hours and re-immersed in the salt solution. The number of cycles for each type of mortar was 70. After each drying phase, the samples were weighed. Efflorescence (incrustations) was not removed from the samples used to measure the weight. At the end of the study, the samples were rinsed with distilled water and dried to a constant mass at 105 °C. Despite the fact that this method does not fully reflect the conditions of real impacts that plasters may be exposed to natural conditions, it allows to

Table 1
The composition of dry mixtures of plasters.

Components	Symbols and composition of dry mixtures, (% by weight)					
	S 1	S 2	S 3	S 4	S 5	S 6
Portland cement CEM 152.5 R	15	15	15	15	15	15
Quartz sand 0.0 ÷ 1.0 mm	73.66	73.36	73.15	72.34	74.69	73.84
Limestone powder 45 μm	5	5	5	5	5	5
Hydrated lime	5	5	5	5	5	5
Pearlite	1	1	1.5	2	–	0.5
HEMC (Hydroxyethyl methyl cellulose)	0.1	0.1	0.1	0.1	0.1	0.13
PVAc (Poly vinyl acetate)	0.2	0.5	0.2	0.5	0.2	0.5
Aerator 1	0.04	0.04	0.05	0.06	0.01	0.03
Aerator 2	0.005	0.01	0.005	0.01	–	–
Water*	24	23	25	26	24	23
w/c	1.6	1.53	1.67	1.73	1.6	1.53

* Water content required to obtain the consistency is specified in relation to the weight of dry ingredients. The consistency corresponds to a flow of 170 ± 5 mm as determined by the flow table method according to PN-EN 1015-3:2000 [25].

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