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Effect of Hydrophobic Materials on Water Impermeability and Drying of Finish Brick Masonry

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By the analysis of experimental data, it is established that the material selected for hydrophobic purpose has caused significantly decrease in water absorption of bricks themselves, but an effect on mortar hasn't been adequate. As a consequence, large moisture volume has got into bricks through mortar joints. The rate of drying (decrease of vapor conductivity) in this case is serving as additional factor in deterioration at freezing-thawing cycles. As a conclusion, it could be stated that the surface protection against water absorption cannot ensure weather durability of finish brick masonry façade, if an opportunity is left for water absorption through the joints in the masonry.

Keywords: ceramic brick masonry, water absorption, surface drying, weather durability.

1. INTRODUCTION

Exterior surface durability of the building walls is important both in the economical and aesthetic aspect. One of the main factors destroying the brick masonry is freezing moisture. During the cold period, the water contacting the surface of the brick masonry as a rain, sleet or melting snow penetrates the deeper layers of the masonry and increases their dampness. Then, if an exterior air temperature reduces, the moisture penetrating the surface layers of the brick masonry freezes in the pores and capillaries and destroys the surface layer starting from the bricks. The destroying effect of the freezing moisture on the exterior surface of the bricks has been analyzed for a long time in many countries [1 – 8]. The fragmentation effect of the freezing moisture under laboratory conditions in the pores of the material is determined by cyclic freezing-heating (with water) effects. The property of the material no to loose aesthetic and power properties after an appropriate number of such effect cycles is called a cold resistance. In cases when the main destroying effect is the freezing moisture, for instance, on ceramic finish bricks, cold resistance is the index of the material's durability [3 – 6; 8]. Many research authors have determined a direct dependency between cold resistance of the brick masonry and water absorption of the bricks, i.e. the higher water absorption of the bricks, the quicker it is destroyed by the cold cycles [9 – 12]. Water absorption of ceramic finish bricks is even considered an indirect index of cold resistance and durability of the brick masonry [10, 12].

One of the ways to protect the brick masonry from the moisture penetrating from the outside is surface impregnation by water push-off materials. The effect of such materials while reducing water impregnation of the bricks is obvious, however, their effect on cold resistance is often a controversy. Both experimental research and natural observations have shown that an inappropriate application of impregnation materials instead of the expected increase of cold resistance and durability of the brick masonry provides with an opposite effect, i.e. bricks crack quicker than the non-impregnated ones [13]. This occurs due to the fact that hydrophobic materials slow down not only the process of water absorption but the drying process as well [14 – 16]. Due to the impregnation–drying balance, the processes of surface fragmentation may speed up.

Therefore the urgent question remains - is it possible while analyzing moisture exchange of the surface layer of the brick masonry to indirectly forecast its cold resistance and durability. It could be done only by analyze experimental investigation.

By reducing water absorption of the material, we expect to increase its cold resistance and durability. On the other hand, water absorption reducing means often also reduce the vapour conductivity, i.e. drying possibilities of the material's surface. The decreasing vapour conductivity of the material (surfaces drying) also reduces cold resistance [11, 17 – 19]. Evaluating water absorption and vapour conductivity of the material's surface, critical boundaries influencing durability of the material must also be optimal [18, 19]. Figure 1 shows the principal scheme for optimization of the material's surface pursuant to physical properties (water absorption, surfaces drying and durability).

On the other hand, the surface of the brick masonry is heterogeneous, as it is composed of the areas of the brick and masonry mortar surfaces. The values of water absorption and vapour conductivity of these surface layers are different as well as the effect of hydrophobic material. This has fostered the more exhaustive research on the effect of these materials on the brick masonry, complexly evaluating their effect of moistening, drying and resistance of the brick masonry on the simulated climatic effects in the climatic chamber.

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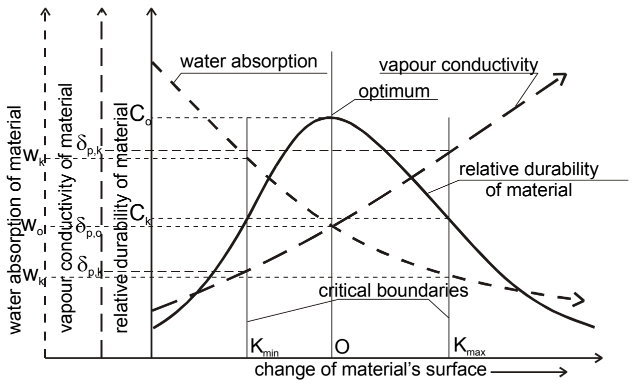

Fig. 1. The principal scheme for optimization of the material's surface to physical properties (vapour conductivity, water absorption, durability) [18; 19]

Aim of the investigations described in the paper - estimation of the effect on the service life for ceramic finish brick masonry coated by hydrophobic material.

2. EXPERIMENTAL

2.1. The research object

Hydrophobization is a process, during which, effected by appropriate chemical compounds, a hydrophilic surface of solid materials becomes dry of water due to chemisorption oriented by the hydrophobizator molecules. Effectiveness and durability of water push-off surfaces depends on the chemical composition, polymerization conditions of a building material and hydrophobizator and relationship formation between hydrophobizator and material parts as well as on sorption depth and optimal quantity of hydrophobizator. Therefore, hydrophobizator effect varies from case to case [20].

Due to interaction of hydrophobizator active groups with hydroxi groups, which are included in the composition of the surface material, a thin polymer layer forms and stratifies: oxygen atoms in the bottom and radicals on the top. This upper layer protects the surface from water absorption, as it pushes off water molecules.

The surface effected in this way looses properties of water moistening and capillary sorption [20]. However, it is known that silicones do not form a homogeneous film on the surface of the material, do not cover all pores and, thus, cannot totally hinder the water from migrating though the large pores [21].

One of the hydrophobic materials silicon Wacker S15 has been chosen for experimental research. It was used for impregnation of the surface areas of the brick masonry by coating with a silicon material using a brush.

2.2. Research methodology

For resistance simulated climatic effect research in the climatic chamber, a ceramic brick wall was built and ceramic finish bricks were used for investigation on its exterior surface. Equipment for simulation of climatic effects was installed on the one side of the wall and the equipment to maintain inner room air conditions - on another. To investigate surface resistance of finish bricks, heat-temperature, precipitation and cold effects were imitated, i.e. an aggressive rainy thaw effect characteristic to a winter period was simulated by moistening-freezing-heating cycles. 24-hour cycle was chosen, which was divided into the following periods:

- 2 h – moistening with water pipe water + (10 ± 2) °C;
- 16 h – freezing to –15 °C;
- 6 h – heating to 25 °C.

Fragmentation of exterior layers during climatic tests was quantitatively evaluated pursuant to worsening and loss degree of decorative properties (layering, cracking, occurring air-pockets, chalking, occurring corrosion spawns, dirt collection, change of colour).

To determine water absorption and drying of the brick masonry, the samples of three types were used: separate bricks, bricks covered with masonry mortar and masonry mortar cubes (Fig. 2).

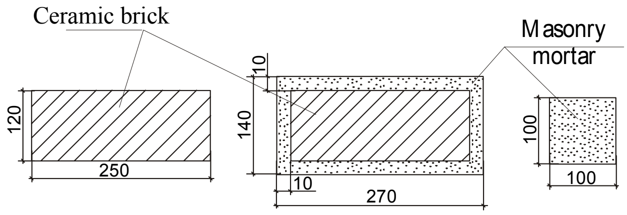

Fig. 2. Schemes of samples used for determination of water absorption and drying

After façade surfaces of these samples were coated with a silicon material, 6 samples groups were formed:

I) ordinary ceramic bricks;

II) silicon covered ceramic bricks;

III) ceramic bricks covered with a masonry mortar along their perimeter;

IV) ceramic bricks covered with a masonry mortar and then with silicon along their perimeter;

V) masonry mortar cubes;

VI) masonry mortar cubes covered with silicon.

While determining surface water absorption of the samples, the samples were weighted before the test, then soaked into the bathtub filled with water of 20 °C temperature with a façade side down to the depth of 2 ÷ 5 mm from the façade surface of the samples. Then the samples were weighted after 1, 2, 3 hours and later once in 24 hours. They were weighted till the moisture spot appeared on the upper surface of the sample or if the sample's mass has stopped increasing.

The same samples underwent also the drying tests. These samples were isolated from all sides by a polyethylene film, except a façade plane, in order the natural drying to go only through this plane. The test was conducted at +20 °C temperature and 50 % of relative humidity in the room. The samples were weighted before the test, then after 1, 2, 3 hours and later once in 24 hours.

2.3. Research results

After testing the effect of a chosen hydrophobic material on the ceramic finish brick masonry in the climatic chamber influenced by the simulated moistening-freezing-heating cycles, a clear negative result was received. The masonry fragments impregnated by a hydrophobic material started to decay considerably earlier than the bricks in the telltale area of the masonry. Research results are presented in Table 1.

Table 1. Resistance of ceramic brick masonry impregnated with silicone S15 to the simulated climatic cycles in the climatic chamber

Impregnation variant of ceramic brick masonry	Number of cycles	
	Start of decay	10 % of surface decay
1. Masonry impregnated once	22	30
2. Masonry impregnated twice	19	35
3. Telltale sample	50	90

Fig. 3. The fragment of ceramic finish brick masonry impregnated with a hydrophobic material after testing by simulated effect cycles in the climatic chamber

Table 2. Surface water absorption

Sample groups	Surface water absorption, W, kg/m^2, per time t, h				
	1	24	48	72	98
I	9.72	25.87	27.00	27.26	27.54
II	0.05	0.12	0.20	0.22	0.25
III	8.12	30.46	33.11	33.42	33.55
IV	2.60	17.60	25.93	28.13	28.97
V	5.35	15.41	16.75	16.82	16.91
VI	2.42	13.84	16.59	16.70	16.84

The table shows a number of cycles, after which the first decay signs were registered on the surface of bricks, and a number of cycles when considerably many decay focuses occurred in a separate fragment of the masonry and the area of decays made about 10 % of the total area of the fragment. This corresponds to situation when damages become clearly seen on the partition surface under the natural conditions. The decay type of the bricks impregnated with a hydrophobic material was very similar in all cases. Decay used to start on the edges of the bricks when the edges commenced to crumble, meanwhile the finish layer existing in the middle of the brick was the last to fall down. Figure 3 shows the masonry fragment of the tested bricks.

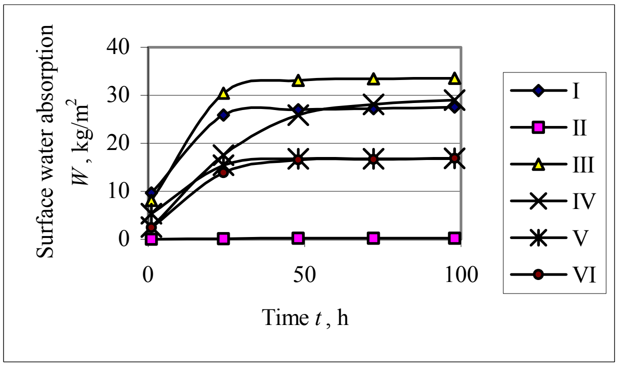

Fig. 4. The curves of surface water absorption for ceramic finish brick masonry impregnated with a hydrophobic material

Table 3. Surface drying

Sample groups	Surface drying, g, kg/m^2, per time, t, h				
	1	24	48	72	98
I	0.05	1.21	2.37	3.57	4.73
II	0.04	0.33	0.54	0.75	0.92
III	0.03	0.67	1.76	2.84	3.92
IV	0.06	1.40	2.39	4.42	5.61
V	0.10	1.38	2.77	4.16	5.23
VI	0.12	1.09	2.13	3.18	4.28

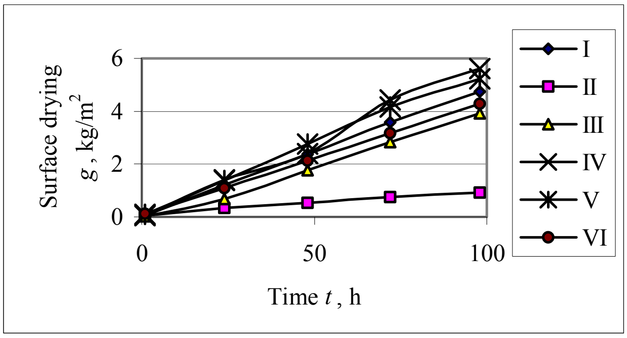

Fig. 5. The curves of surface drying for ceramic finish brick masonry impregnated with a hydrophobic material

According to the test results in the climatic chamber, it is seen that the chosen hydrophobic material has reduced resistance of the brick masonry to complex rain-cold-heat effects more than twice. In order to more exhaustively investigate the reasons of this result, the tests were conducted to find out the moisture movement in the exterior surface layer of the impregnated brick masonry. Water absorption and drying were determined by the tests conducted pursuant to the methodology described under the section 3. Test results are presented in Tables 2 and 3 as well as Figures 4 and 5.

2.4. Generalization of research results

After water absorption test it was determined that impregnation of the brick surface reduces water absorption by more than 100 times. This proves the significance of hydrophobization. Conducting the analogous test with bricks, the edges of which were coated with a masonry mortar, the effect of surface impregnation has reduced up to 30 %. Surface impregnation of the samples made only from the masonry mortar only slightly reduces water absorption and only at the primary moment of absorption but within two days these sizes were almost equalized.

This may be explained by a mechanism of hydrophobization process in the materials of different pore density.

As pore density of the masonry mortar is high, silicon cover cannot protect the whole surface from water penetration. Knowing that the layout of silicon macromolecules on the hydrophilic surface reminds the "chess" order, they cannot protect all pores, thus, a part of water molecules, which meet no silicon macromolecules on their way, penetrate deeper into the material. Therefore, water absorption of the samples of these groups is high and very similar.

Comparing the samples of all groups, we can draw a conclusion that the influence of water absorption and hydrophobization also depends on homogeneity.

Homogeneity predetermines similarity of the pores, thus, water distribution of the samples of the groups I and II and V and VI is linear. Waterfront is completely the same. Separate ceramic bricks, the pores of which are smaller than of the masonry mortar cubes, justify hydrophobization with silicones.

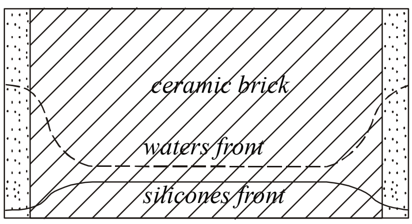

Fig. 6. The distribution of water and silicone in the ceramic brick masonry

Figure 6 shows the distribution of silicone and water in the ceramic brick masonry (or in the brick, the edges of which are impregnated with a masonry mortar (samples of group IV)).

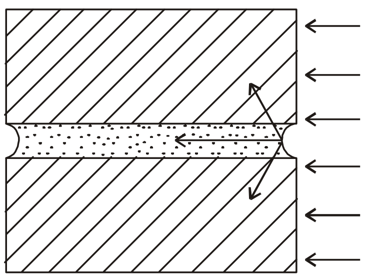

Fig. 7. The scheme of water migration in the ceramic brick masonry

As it was already mentioned, mortar pores are bigger and a silicone film cannot fully cover them, therefore, the level of the water absorbed is higher than of the a ceramic brick itself. In this case water penetrates the brick pores not only from the façade side but also from the sides through the mortar seams (Fig. 7).

Measuring the drying process of the samples, it was determined that impregnation of the brick surface reduces the drying by approximately 5 times, and of the masonry mortar – by 15 – 20 %. The difference between the drying of a non-impregnated brick and masonry mortar is only slight.

3. CONCLUSIONS

Pursuant to the research results, we can draw the following conclusions:

1. Water absorption of ceramic finish brick masonry is higher than of the separate bricks and of the masonry mortar. Water penetrates the bricks not only through the façade surface of the brick but also through the seams impregnated with the masonry mortar;
2. Impregnation with the silicone Wackar S15 reduces water absorption of a ceramic brick but only slightly effects the ceramic brick masonry. This is predetermined by a different density of a brick and masonry mortar seam;
3. Hydrophobic material Wackar S15 considerably reduces the drying of the brick, however, only slightly effects the drying of the masonry mortar;
4. Impregnation of the surface of ceramic finish brick masonry with the silicone S15 damages a moisture exchange balance on the surface layer, therefore, this reduces cold resistance of the brick edges;
5. As impregnation of the bricks considerably reduces water absorption and only slightly – the drying, then cold resistance in the middle of the brick is not reduced;
6. Protection of the façade surface of ceramic finish bricks from water absorption does not ensure their durability, if a possibility for brick impregnation through masonry seams remains, as hydrophobization of the finish brick masonry reduces its cold resistance due to unequal hydrophobization effect on the brick surface and masonry mortar;
7. Inappropriately chosen hydrophobic materials may worsen durability of the brick masonry by changing the balance of brick impregnation and drying.

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