Study of the efficiency and durability of hydrophobization modifications of building elements

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Study of the efficiency and durability of hydrophobization modifications of building elements

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Abstract. One way how to limit the effect of increased moisture on building constructions is the hydrophobization of these constructions or parts thereof. However, hydrophobization protection may be subjected of degradation effects that may reduce its effectiveness. The contribution deals with monitoring the degradation degree of hydrophobization protection of ceramic masonry elements caused by climatic effects. There is a comparison available between accelerated/simulated degradation and non-accelerated real-time degradation. The results are compared with the real capillary absorption of the untreated/non-hydrophobized wall blocks.

1. Introduction

Increased moisture has a negative effect on most building materials and acts as a degradation factor that negatively affects the properties and lifetime of building constructions [1, 2, 3].

For this reason, a number of waterproofing measures are used during construction of building constructions to protect the building construction from the adverse effects of water and moisture.

The protection of the building construction from the effect of rainfall and ground moisture is mostly covered with coating waterproofing, but there are also solutions utilizing special elements with very low water absorption, such as hydrophobized skirting masonry blocks [4]. These blocks can be used in the area of masonry establishing and serve primarily as masonry protection during construction. Hydrophobization adjustment of the blocks prevents soaking and capillary rising of the moisture from the base of the foundation and the base belts into the masonry while the construction as a whole is not protected from the effects of rainfall moisture.

Furthermore, the skirting blocks serve as additional waterproofing measure if the primary waterproofing protection - mostly asphalt or rubber belts – fails [5].

The agents used for the treatment of skirting blocks are the most commonly silicone-based polymers [6]. Even these products, like most polymers, are susceptible to degradation due to climatic effects, especially UV radiation. During construction, it is common that the period before covering of the skirting elements by surface protection ranges between 0.5 and 2 years. During this time, the skirting elements are subjected to UV radiation, which can degrade their waterproofing effects. The process of hydrophobization protection is most often carried out by dipping the blocks into a hydrophobization solution of a given concentration.

Hydrophobization preparations are currently mostly applied only to parts of the masonry elements. However, in the scope of the realized experiments, the whole hydrophobic elements were tested, loaded with the extreme case, i.e. flooding the entire wall element.

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2. Methodology of testing the degradation of hydrophobization protection

In order to monitor the degradation of hydrophobization protection applied to the masonry elements due to climatic effects, ceramic masonry blocks of the Therm type for a wall thickness of 300 mm were selected. Two sets of test samples were made on which silicon-based hydrophobic agents at a concentration of 1:40 were applied by dipping for 10 s together with the pigment indicating the hydrophobized blocks (similar to commercial products). These were two sets of blocks that were hydrophobized to the full height of the blocks.

The used hydrophobization agents were based on:

- Sample A: silicon compound, nonylphenol and ethoxylate,
- Sample B: silan-siloxan.

To determine the degradation of hydrophobization protection, an accelerated aging method was chosen using load cycling due to temperature, moisture and UV radiation.

One simulation cycle consists of 170 minutes of water sprinkling using spraying jets that sprays about 103 litres of water per 1 m^2 of the effective area per hour. These 170 minutes of sprinkling is followed by a 10-minute pause. After the pause, the test sample is heated for 170 minutes using an IR lamp of about 1300 W per 1 m^2 with the addition of UV light of 250 W per 1 m^2. The temperature of the radiant area of the exposed material increases to about 60–70°C. This is again followed by a 10 minute pause. The procedure described above is repeated 17 times in succession. The samples are then left in water for 2 hours. After 2 hours of water saturation, the samples are placed in a climatic chamber at -20°C for 2 hours. This completes one simulation cycle of the durability test, which corresponds to the exposure of the samples to the outdoor environment under extreme conditions for a Central European locality for 1 year.

To create the necessary conditions, a device was used which is referred to as a „sprinkler“ (see figure 1). It is equipment of Research Institute for Building Materials. The degradation simulation was carried out as part of the collaboration between research institutions.

Figure 1. The device for simulation of load cycles.

From each set of hydrophobized blocks, a sample was placed in a water bath for about 1 month (see figure 2). The water level was maintained above the upper surface of the blocks. Thus, the effectiveness of the hydrophobization protection on blocks was determined using the selected hydrophobization agents A and B. The efficacy was determined by monitoring the absorbance of the blocks over time. At the selected time intervals, the blocks were always drawn out of the water bath, for about 30 seconds the blocks were loosely placed on the pad for sufficient draining of surplus water from the surface of the block. Blocks were then weighed and put back into the water bath.

The capillary absorption (1) was calculated from the weight gain of the blocks over time (in selected periods) due to the water absorption into the pieces of block in relation to the masonry block surface.

$$C_a = \frac{m_{w,cb} - m_{d,cb}}{A} \tag{1}$$

C_a – capillary absorption [kg.m^{-2}]
$m_{w,cb}$– weight of wet ceramic block [kg]
$m_{d,\,cb}$– weight of dry ceramic block [kg]
A – surface ceramic block of stress of water [m^2]

Figure 2. Placing of blocks in a water bath - determination of capillary absorption.

For comparison, the absorption on the non-hydrophobized masonry block with REF marking was determined under the same conditions (see figure 3).

As can be seen from figure 3, the non-hydrophobized masonry element already has significant capillary water absorption over 8 kg.m^{-2} in the first hour of water bath placement. At 100 h, the capillary absorption rate gradually increases up to 9 kg.m^{-2}. The untreated blocks, thus absorbs more than 9 l of water over its surface.

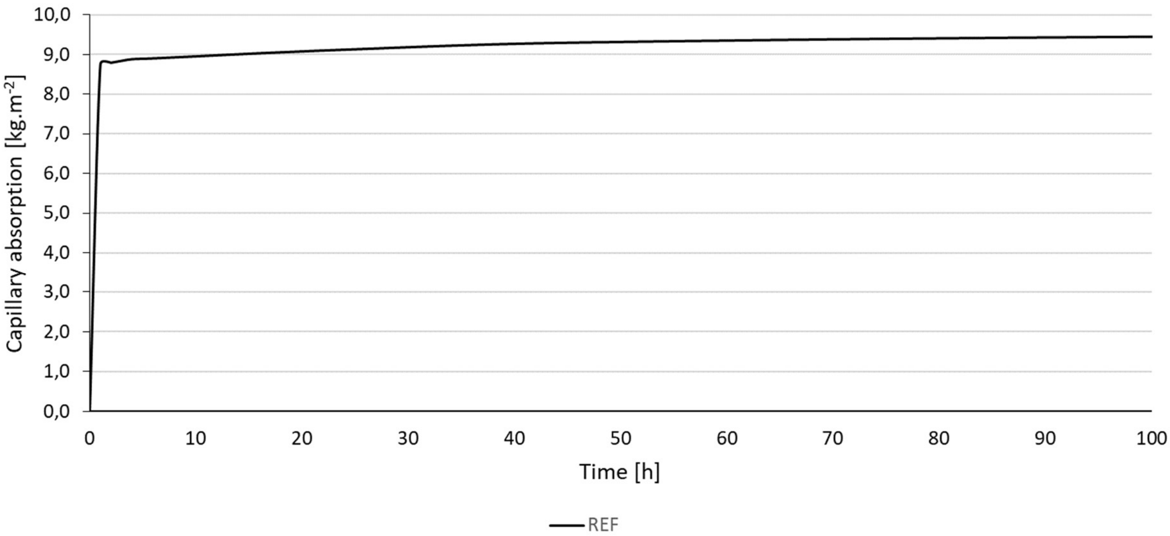

Figure 3. The capillary absorption of samples without the utilization of hydrophobization agents.

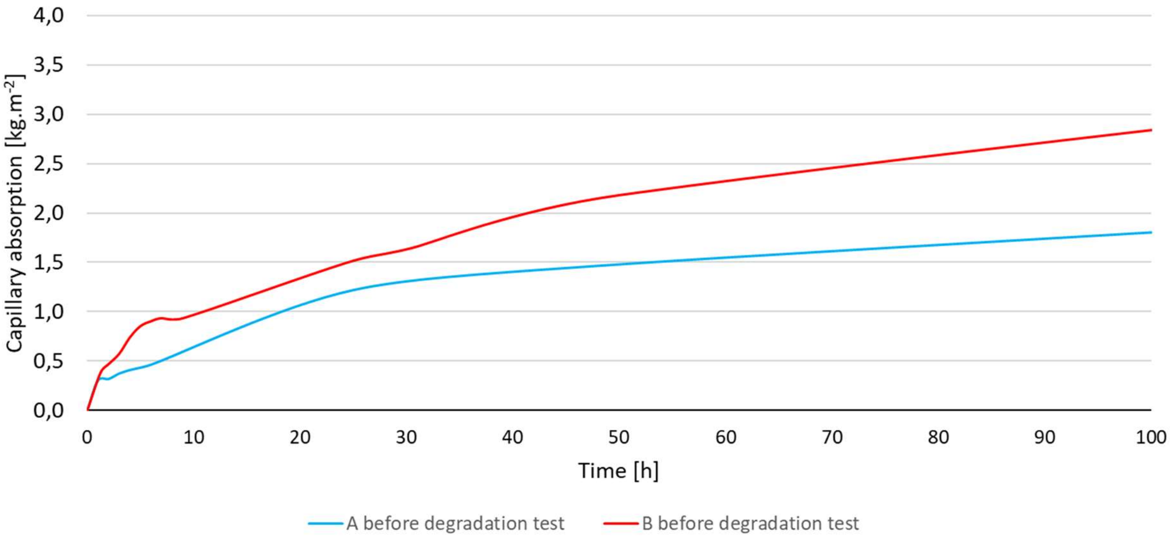

Figure 4. The absorption of test samples with hydrophobization agents.

By using hydrophobization agents, there was a slowdown of capillary absorption of the blocks in both cases (see figure 4 and table 1). The use of agent A reduced the capillary absorption rate, whereupon the treated block absorbed 70% less in the first 100 hours compared to the non-hydrophobized block, i.e. below 2 $kg.m^{-2}$.

Table 1. Change of capillary absorption after hydrophobized test samples.

Time [h]	24		48		96	
REF	9.12		9.31		9.42	
A before degradation test	1.22	- 86.6 %	1.46	- 84.3 %	1.75	- 81.4 %
B before degradation test	2.18	- 76.1 %	2.21	- 76.3 %	2.83	- 70.0 %

3. Hydrophobization protections under the influence of UV

The results of capillary absorption after exposure to accelerated aging test due to climatic effects are shown in table 2 and figure 5 below. The simulation of aging occurred within one cycle, corresponding to 1 year aging due to extreme climatic effects.

Table 2. The comparison of absorption of hydrophobized test samples before and after simulation of aging due to climatic effects.

Time [h]	0	5	24	48	72	96
REF	0.00	8.88	9.12	9.31	9.31	9.42
A before degradation test	0.00	0.43	1.22	1.46	1.57	1.75
A after degradation test simulation	0.00	0.81	1.58	2.11	2.23	2.61
B before degradation test	0.00	1.24	2.18	2.21	2.52	2.83
B after degradation test simulation	0.00	2.58	3.73	3.83	3.84	3.89

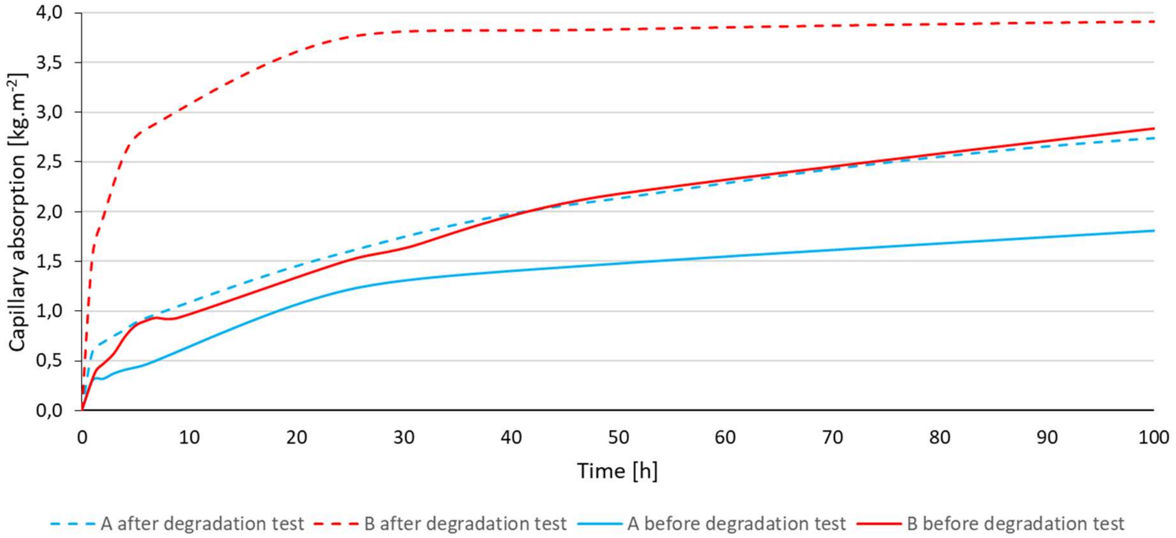

Figure 5. The comparison of absorption of hydrophobized test samples before and after simulation of aging due to climatic effects.

As expected, it is evident that the accelerated aging test has degraded the hydrophobization protection. Degradation occurred in both tested hydrophobization agents A and B in similar limits. Due to the accelerated aging test as a result of climate degradation test, the capillary absorption of hydrophobized blocks increased by about 60% over 100 hours. However, the capillary water absorption did not exceed 4 $kg.m^{-2}$ in the first 100 hours, compared to the absorbance of the reference block, which contains a capillary absorption of more than 9 $kg.m^{-2}$ at 100 hours.

Values obtained from the accelerated climate degradation test were also compared with the non-accelerated test. The non-accelerated aging test was performed on blocks on which the hydrophobization protection efficiency was determined. Based on the results of the accelerated test, it was only continued with the hydrophobization agent A testing, the application of which before and after the acceleration of the aging test resulted in a lower capillary absorption than when using hydrophobization agent B. The results of the accelerated aging due to climate degradation test are shown in table 3 and figure 6.

Table 3. Comparison of absorption of hydrophobized test samples before and after natural aging due to UV radiation.

Time [h]	0	5	24	48	72	96
REF	0.00	8.88	9.12	9.31	9.31	9.42
A before degradation test	0.00	0.43	1.22	1.46	1.57	1.75
A after degradation test	0.00	0.81	1.58	2.11	2.23	2.61
A after nature degradation test	0.00	0.71	2.04	2.48	2.84	3.23

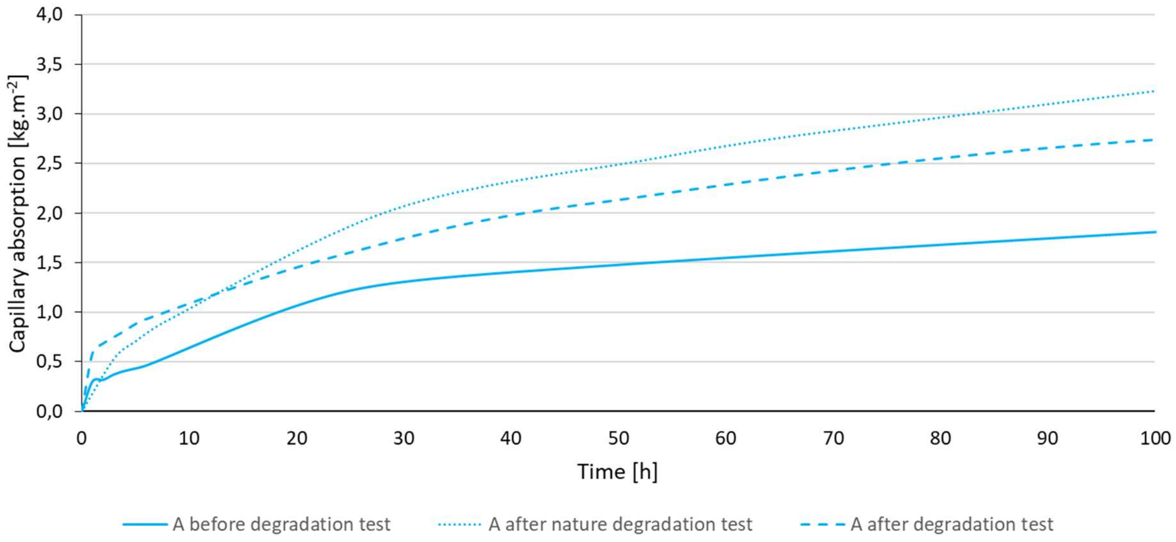

Figure 6. Comparison of absorption of hydrophobized test samples before and after natural aging due to UV radiation.

In the case of a non-accelerated/natural test of aging for 1 year, a very similar degree of degradation was demonstrated as in the case of an accelerated aging test due to a combination of climatic effects (see table 4). The capillary absorption of the samples after 1-year degradation due to climatic effects did not increase in a period of 100 hours above the value of 3.5 kg.m^{-2}.

Table 4. Change of capillary absorption after aging due climatic effects.

Time [h]	24		48		96	
A before degradation test	1.22		1.46		1.75	
A after degradation test	1.58	29.5%	2.11	44.5%	2.61	49.1%
A after nature degradation test	2.04	67.2%	2.48	69.9%	3.23	84.6%

4. Conclusion

Tests have shown that using a suitable hydrophobization agent, ceramic masonry blocks can be effectively protected against the effects of increased moisture. If these bocks are used to construct the establishing as test samples, they effectively prevent the moisture absorption into the masonry and the subsequent capillary rising of moisture. This modification of the samples exhibits very long-term stability and is not significantly degraded by climatic effects - especially UV radiation.

It has been proven that degradation due to climatic effects does not have a significant impact on final absorption. Samples treated with a hydrophobization agent based on silicon compound, nonylphenol and ethoxylate after aging test acceleration (equivalent to 1 year in real time) due to UV radiation do not show capillary absorption higher than 4 kg.m^{-2} over a period of 100 hours with a continuous load by standing in the water. Capillary absorption of untreated blocks under the same conditions is about 9.5 kg.m^{-2}. It is also necessary to take into account that the test carried out was an extreme case of increased moisture load, which, in real conditions, occurs exceptionally.

The results of the effect of hydrophobization coincide with the results obtained in the framework of similar scientific works [7]. The study of hydrophobic protection of ceramic elements and its degradation will continue, the aim will be to obtain comprehensive information on this issue.

The only and most significant degradation effect of the hydrophobization protection of the ceramic masonry block is therefore the mechanical damage of the hydrophobized part of the block.

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