

THE INFLUENCE OF LITHIUM WATER GLASS ON THE DURABILITY OF CONCRETE

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ABSTRACT. The aim of the research is to verify the effect of lithium water glass on the durability and reduction of concrete absorption. For this purpose, the absorption test was made and the influence of the impregnation agent on durability when the test specimens are exposed to cyclic freezing and thawing was verified. Finally, the permeability of the test specimens was measured before and after impregnation. On the basis of the tests carried out, the effect of the impregnation agent was determined by comparing impregnated test specimens with reference specimens.

KEYWORDS: Concrete, hydrophobic impregnation, water absorption, durability.

1. INTRODUCTION

Nowadays, when the attitude to the environmental protection changes and when more and more attention is paid to the limited reserves of mineral raw materials, there are changes also in the field of construction. For example, for long bridges it is considered that they should safely resist the effects of loading for up to 200 years [1]. It is necessary to adapt the building materials to this.

Concrete is a very resistant and durable building material. However, its durability can be influenced by the amount and type of pores contained in the concrete. During its lifetime, water and aggressive substances penetrate the porous structure of concrete, which can cause a number of degradation processes, for example corrosion of reinforcement, corrosion of concrete or alkali-silica reaction.

As a result of these degradation processes, micro cracks appear and expand, which allows the penetration of a larger amount of water and aggressive substances. Over time, the concrete structure may collapse completely.

2. SURFACE PROTECTION

In order to limit the amount of water penetrated into the porous structure of concrete, it is possible, in addition to changing the composition of the concrete mixture itself, to apply surface protection to the surface of the concrete structure.

According to ČSN EN 1504-2, types of surface protection can be divided into three groups:

- Hydrophobic impregnation (Figure 1) – the surface of the concrete is treated with a hydrophobic agent that has an effect on the size of the wetting angle. There is no reduction in the diameter of pores and capillaries.
- Impregnation – concrete is provided with a treatment that reduces its surface porosity and strength-

ens the surface. Pores and capillaries are partially or completely filled.

- Coating – after application of the coating, a continuous protective layer is formed on the concrete surface [2].

2.1. HYDROPHOBIC IMPREGNATION

When concrete comes into contact with water or another liquid, this liquid soaks into the pores of the building material due to the action of capillary forces. Assuming a straight cylindrical capillary, the capillary force F_{kap} acting in this way can be defined by the following relation:

$$F_{\text{kap}} = 2\pi\gamma r \cos\theta, \quad (1)$$

where γ is the surface tension of the liquid, r is the pore radius, and θ is the wetting angle of the liquid on the surface of the solid. It follows from the equation that the larger the wetting angle θ , the smaller the capillary force [3].

On a concrete surface without surface treatment, water easily soaks into the concrete structure due to the small wetting angle. When a drop of water hits the concrete surface, it spills to the sides.

When applying a hydrophobic impregnation, a thin layer is formed on the surface of the concrete structure, which causes an increase in the wetting angle θ (Figure 2) that leads to a reduction in the capillary force F_{kap} . In practice, it means that when a drop of water falls on a concrete surface treated in this way, the drop remains wrapped in a ball and runs off the surface. Its contact with the concrete surface is minimal which leads to a fundamental reduction in absorbency [4].

3. THE PROCESS OF IMPREGNATION

A solution of lithium water glass is used as a hydrophobic impregnation. It is assumed that after its applica-



FIGURE 1. Hydrophobic impregnation, impregnation, coating (from the left side) [2].

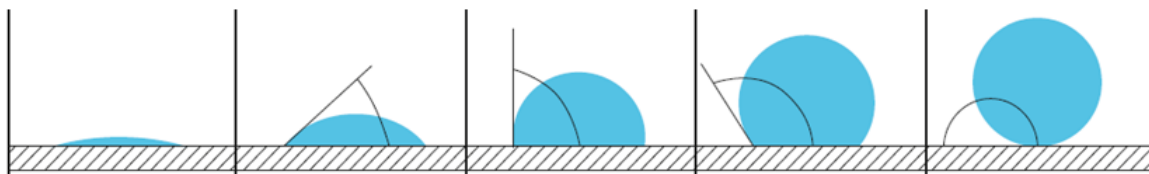


FIGURE 2. Increase in wetting angle [4].

tion to the surface of the test specimens, the wetting angle of the surface will increase and thus the water absorption will fundamentally decrease (Figure 3). At the same time, there should be no reduction or complete filling of the capillary pores. The influence on the size of the wetting angle can be seen from the following picture, where the top is a non-impregnated test specimen and the bottom is an impregnated one.



FIGURE 3. The influence of impregnation on the size of the wetting angle.

After its application to the surface of the test specimens, the solution penetrates into the pores and chemically reacts with the calcium ions contained in the hardened cement paste, forming calcium silicate hydrate (C-S-H). It gradually hydrates and creates a crystalline structure, which reduces the absorbency of the surface.

For the purpose of the experiment, three series of test specimens were made from hardened cement paste. Each series contained 12 blocks measuring $40 \times 40 \times 160$ mm. In the third series, 12 blocks with dimensions of $150 \times 150 \times 50$ mm were also made. A mixture of cement CEM I 42.5 (Heidelberg Cement Group, závod Mokrý) and water with a water cement ratio of 0.28 was used for their production.

After their hardening and treatment, the series of

test specimens was divided into six reference specimens and six impregnated specimens. In the case of test specimens intended for impregnation, the surface was grinded using 60 grit and then 240 grit sandpaper and cleaned. Then the specimens were immersed in a lithium water glass solution for 5 min. This was followed by 24 hours of drying on suitable mats so that all six sides of the surface of the blocks could be dried.

4. TESTING

4.1. ABSORPTION TEST

The aim of the water absorption test is to verify the rate of water absorption of impregnated and non-impregnated test specimens based on the differences in their weights before soaking and after a certain period of time, and then to compare the results. A prerequisite is slower water absorption for impregnated test specimens, especially in the first minutes.

The weight of all test specimens must be considered before soaking. Subsequently, the specimens are placed in a container of water on suitable mats so that the water surrounds them from all sides (Figure 4). The weights of the individual test specimens are measured after 10 min, 0.5 h, 1 h, 2 h, 3 h, 5 h and 24 h from the moment of their immersion in water. The test specimens are taken out of the water at given time intervals, their surface is wiped with a wet cloth to remove excess water, and their weight is weighed. Immediately afterwards, the specimens are put back into the water.

For each time interval, the difference in the weight of the test specimen is determined and compared to its initial weight. Their percentage is determined from the average of the differences in the weights of the individual impregnated and non-impregnated test specimens compared to their weight before soaking.

Impregnated test specimens absorb only 55 % of the amount of water during the first test performed in the first interval compared to non-impregnated test specimens. Over time, the amount of absorbed water is gradually equalized. Impregnation has the greatest



FIGURE 4. The impregnation of the test specimens.

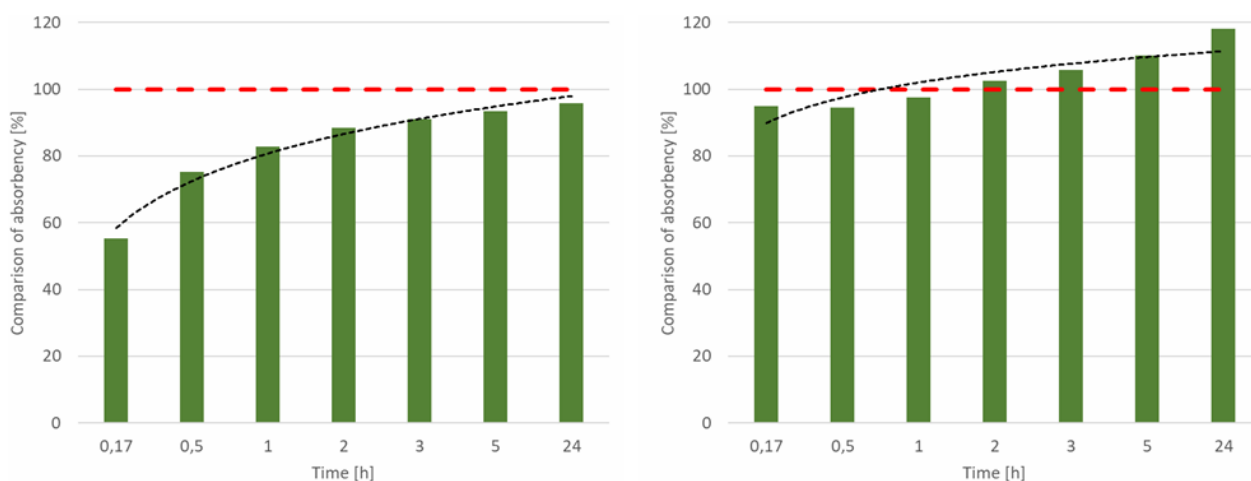


FIGURE 5. The results of the first and second tests of the first series of test specimens.

influence in the first hours of the test (Figure 5). When the test is repeated with the same test specimens three weeks later, the effect of impregnation is already smaller, but still noticeable at the beginning of the test.

Between the first and second absorption test of the second series of test specimens (Table 1), the specimens were placed in a freezer box, where a test of resistance against the cyclic action of freezing and thawing took place. During this, the surface of the impregnated test specimens was significantly damaged, which had a major impact on the course of the second absorption test, during which the non-impregnated specimens, whose surface was almost undamaged, absorbed less water (Figure 6).

The third series of test specimens was first placed in a freezer box, where a test of cyclic action of freezing and thawing took place. In this case, there was no significant damage on the surface of the impregnated specimens, as was the case with the previous series. Before starting the absorption test, not enough time had passed since the specimens were taken out of the freezer box, and a considerable amount of water

Series	Absorption No. 1	Freezing and thawing	Absorption No. 2	Porosity
1	X		X	
2	X	X	X	
3		X	X	
3-P				X

TABLE 1. The tests performed on each series.

remained in their pores. This is reflected in the test results, where there isn't any effect of impregnation and the specimens absorbed much less water compared to the other tests (Figure 7).

The amount of water that bodies can hold is directly proportional to their pore volume. If part of the pore volume is already filled with water, only the remaining volume can be filled during soaking.

The test specimens were dried in a laboratory environment and their weight before the start of the second test was higher than before the first test. The resulting weights of the test specimens immersed in water for 24 hours during the second test are the same as their weights at the end of the first absorption

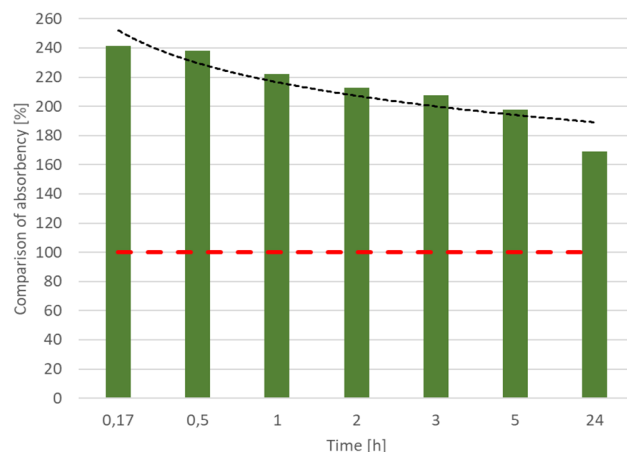
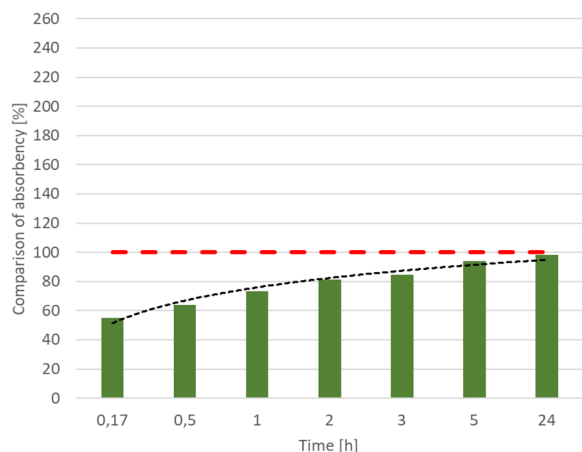


FIGURE 6. The results of the first and second tests of the second series of test specimens.

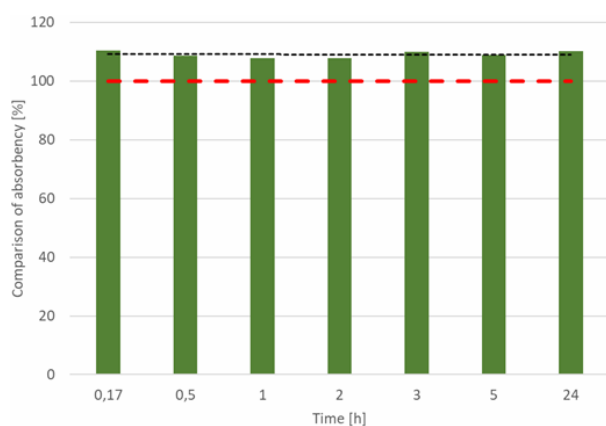


FIGURE 7. The results of the test of the third series of test specimens.



FIGURE 8. Test specimens placed in a freezer box.

test. Therefore, at the start of the second test, the test specimens were not perfectly dry and could not absorb the same amount of water as they did in the first test.

4.2. TEST OF RESISTANCE AGAINST THE CYCLIC ACTION OF FREEZING AND THAWING

With this test, it is possible to observe the level of surface degradation of test specimens after their exposure to a certain number of freezing and thawing cycles. It is assumed that the surface of impregnated test specimens will be less damaged after completion of all cycles than the surface of non-impregnated test specimens.

The test specimens are placed in the freezer together with the temperature sensors (Figure 8). At the beginning, the environment of the freezer box is cooled with cold air to a temperature of -20°C . After 120 min of maintaining the temperature, the environment is heated by infusing water at a temperature of 20°C . This temperature is maintained for 180 min. After the water is pumped out, cooling takes place again. In this way, 25 cycles were completed.

During the test, the pores of the test specimens are

saturated with water. When the temperature drops below the freezing point, the water in the pores turns into ice crystals, increasing its volume up to nine percent. As a result of the increase in the volume of water contained in the pores, pressure arises, which can cause the formation and development of cracks.

In the second series of test specimens, which had already passed the absorption test once, there was significant damage to the surface of the impregnated test specimens, while the non-impregnated test specimens remained almost undamaged (Figure 9). On the contrary, in the test specimens of the third series, which did not pass any other test before being placed in the freezer box, the surface of the non-impregnated specimens was damaged, while the impregnated test specimens remained without visible damage (Figure 10).

4.3. THE INFLUENCE OF IMPREGNATION ON SURFACE POROSITY

The last test performed was the effect of impregnation on surface porosity. The permeability test measures the depth of air penetration into the pores of the test specimens. After determining the specific electrical resistance of the test specimens and the depth of penetration, the quality of their surface can be determined

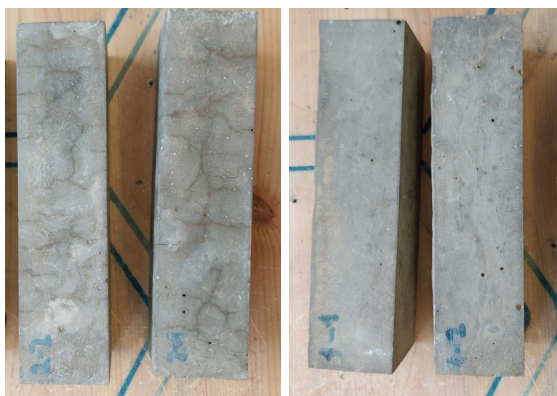


FIGURE 9. Series 2 after being taken out of the freezer box, impregnated and non-impregnated test specimens from the left.

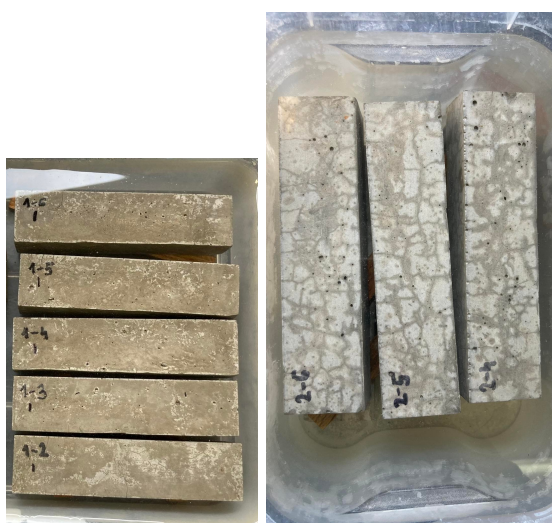


FIGURE 10. Series 3 after being taken out of the freezer box, impregnated and non-impregnated test specimens from the left.

(Figure 11). Hydrophobic impregnation should not cause any reduction in the diameter of pores and capillaries. In the case of impregnated test specimens, it is assumed that the degree of permeability will be maintained while the specific electrical resistance increases.

For six test specimens, the specific electrical resistance and penetration depth L were measured and the quality coefficient of the covering layer kT was determined. The surface of the specimens was grinded and the values were measured again. This was followed by impregnation and drying for 24 hours, after which the values were measured again.

After grinding, there was an increase in electrical resistance. On the contrary, after the impregnation agent was applied, the specific electrical resistance of the test specimens decreased, although the assumption was the opposite. It can be assumed that the electrical resistance decreased due to higher humidity caused by insufficient drying of the test bodies after their impregnation.

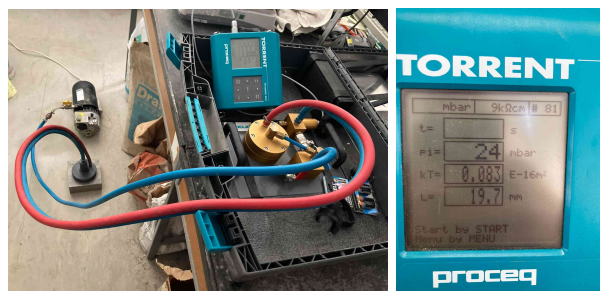


FIGURE 11. Measurement with the Torrent device and display of measurement results.

The coefficient of quality of the covering layer kT , as well as the penetration depth L , increased after the application of the impregnating agent. The impregnating agent has no effect on the reduction of the capillary pores (Table 2). The coefficient of quality of the covering layer can be classified as normal in both cases.

5. CONCLUSION

The results of the absorption tests show that the impregnating agent has a significant effect on the absorption of the concrete. In the first few minutes, it reduces the absorption up to 55% compared to the values of the non-impregnated test specimens. When the test is repeated on the same series of test specimens, the effect of the impregnation is much lower.

The performance of the freeze-thaw cycling test also affects the results of the absorption tests. The impregnated surface was damaged on the second series of test pieces. However, when this test was repeated on a third series of test pieces, the effect of impregnation was negligible.

For the permeability test, there was no significant improvement or degradation in the surface layer quality and pore size of the test pieces. The values changed only minimally, and this difference can be attributed to the change in humidity after immersion of the test pieces in the impregnation solution.

It is demonstrable that hydrophobic impregnation from a lithium hydroxide solution has a positive effect on the durability of concrete structures. For its full use in practice, it is necessary to continue the research, to verify its effects with different composition of concrete mixtures and its effectiveness in the long term.

Hydrophobic impregnation, impregnation and coatings are undoubtedly a good way to go with the contemporary requirement for long durability of concrete structures.

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	Weight [g]	After grinding				kT	L [mm]	Weight [g]	After impregnation				kT	L [mm]
		Resistance [k Ω cm]							Resistance [k Ω cm]					
		I.	II.	III.	Avg.				I.	II.	III.	Avg.		
2-1	2320.30	10.0	9.6	10.0	9.97	0.058	16.3	2325.65	9.6	8.9	8.7	9.07	0.127	24.1
2-2	3044.55	6.7	6.5	6.9	6.70	0.086	19.8	3050.09	6.4	6.4	6.5	6.43	0.213	31.1
2-3	1955.98	13.0	13.0	13.0	13.03	0.150	26.1	1960.96	13.0	13.0	12.0	12.53	0.190	29.3
2-4	3015.22	7.0	6.5	7.1	6.87	0.198	30.1	3020.39	6.4	6.3	6.6	6.43	0.356	40.1
2-5	2088.31	12.0	12.0	12.0	12.20	0.181	28.7	2093.88	12.0	11.0	12.0	11.80	0.230	32.2
2-6	2745.00	7.4	7.3	7.8	7.50	0.108	22.2	2749.65	6.7	6.8	6.9	6.80	0.253	33.8
Avg.	2528.23				9.38	0.13	23.87	2533.44				8.84	0.23	31.77

TABLE 2. Results of the permeability test, test specimens after grinding and after impregnation.

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