

# ENHANCEMENT OF CONCRETE WATERPROOFING PROPERTIES BY IMPREGNATION METHOD

Karimjonova Nazokat Ulmas kizi  
TACI

## Abstract

This article examines the enhancement of concrete waterproofing properties by surface impregnation. The relevance of the topic is determined by the high vulnerability of concrete and reinforced-concrete structures to water penetration, capillary suction, corrosion processes, freeze–thaw deterioration and leaching of hydration products. The purpose of the study is to assess the effectiveness of impregnating compositions in reducing permeability and improving the durability indicators of hardened concrete. The paper systematizes the mechanisms of moisture transfer in concrete, characterizes the main types of impregnating materials, and presents a comparative experimental assessment of untreated specimens and specimens treated with sodium-silicate and organosilicon compounds. The results show that impregnation significantly reduces water absorption and capillary moisture uptake and increases water impermeability; at the same time, silicate treatment also provides moderate strengthening of the surface layer. It is substantiated that the impregnation method is an effective technological solution for preventive protection and rehabilitation of concrete structures operated under humid and aggressive environmental conditions.

**Keywords:** Concrete, waterproofing, impregnation, permeability, capillary absorption, hydrophobic treatment, durability.

## Introduction

Concrete is the most widely used artificial stone material in modern construction. Its extensive use in civil, industrial, hydraulic and transport engineering is explained by its technological adaptability, high compressive strength, economic accessibility and compatibility with steel reinforcement. At the same time, the long-term serviceability of concrete structures is largely determined not only by strength but also by resistance to water penetration. In real operating conditions, moisture acts as the main carrier of destructive agents, because together with water chlorides, sulfates, carbon dioxide and other chemically active substances penetrate into the pore space of concrete and gradually reduce the durability of the structure.

Although hardened concrete appears dense and monolithic, from the standpoint of materials science it is a capillary-porous body. The cement matrix contains gel pores, capillary pores, air voids and microcracks formed during hydration, drying shrinkage, thermal effects and service loading. If these channels remain interconnected, water is able to move into the body of concrete due to capillary suction, pressure filtration and diffusion. As a result, reinforcement

corrosion intensifies, freeze–thaw resistance decreases, salts crystallize in the pore structure, surface peeling develops and repair costs increase.

For this reason, improving the waterproofing properties of concrete remains one of the key scientific and practical tasks of building materials engineering. Traditional solutions include reducing the water–cement ratio, adding mineral or chemical admixtures, using dense aggregates, applying membranes and multilayer coating systems. However, these solutions are not always technologically convenient, especially for existing buildings and structures that already require operation, maintenance or rehabilitation. In such conditions, post-treatment of hardened concrete with protective impregnations becomes especially relevant.

The purpose of this article is to substantiate the effectiveness of the impregnation method for increasing the waterproofing properties of concrete and to evaluate the changes in basic physical and mechanical indicators after treatment. The objectives of the study are: to analyze the causes of water permeability in concrete; to characterize the main types and mechanisms of impregnating compositions; to compare untreated and treated samples experimentally; and to formulate practical recommendations for the engineering application of the method.

### Literature Review and Theoretical Background

The issue of water transfer through concrete has long occupied an important place in construction science, because permeability is directly connected with structural durability. It is widely accepted that the intensity of moisture penetration depends on the total porosity, the distribution of pore sizes, the connectivity of capillaries and the existence of defects in the near-surface zone. According to the classical concepts of concrete technology, the water–cement ratio is one of the primary factors governing capillary porosity. The higher the water content in the fresh mix, the greater the number of voids remaining after hydration and evaporation. This worsens both water absorption and resistance to water pressure.

At the same time, the permeability of concrete is affected not only by the mix design, but also by compaction quality, curing conditions and service-induced cracking. In practice, even structurally strong concrete may exhibit insufficient waterproofing if the near-surface zone is poorly compacted or exposed to drying shrinkage. For this reason, researchers and engineers distinguish between integral and surface methods of waterproofing improvement.

Integral protection involves changing the structure of concrete during production by using supplementary cementitious materials, crystalline admixtures, hydrophobic additives and polymer modifiers. Surface protection, in turn, includes paints, mastics, membranes and impregnations applied to already hardened concrete. Among these, the impregnation method is particularly attractive because it does not require substantial change in geometry or multilayer coating thickness. Instead, the treatment penetrates into accessible pores and modifies the surface layer from within.

Impregnating compositions can be divided into several major groups. The first group includes silicate-based densifiers such as sodium, potassium or lithium silicates. These compositions react with calcium hydroxide in the cement stone and promote the formation of additional insoluble calcium silicate hydrates. As a result, the accessible capillary system is refined and the surface layer becomes denser. The second group includes organosilicon hydrophobic



materials, primarily silanes and siloxanes. Their action is based on changing the surface energy of capillary walls, which reduces wetting and inhibits capillary suction. The third group includes polymeric impregnations, such as epoxy, acrylic and polyurethane systems, which may fill pores and improve resistance to various liquids, although their vapor permeability and long-term performance differ depending on composition.

Thus, the theoretical basis of the impregnation method lies in two main mechanisms: densification of pore structure and hydrophobization of capillary walls. The practical effectiveness of each mechanism depends on the condition of the substrate, moisture content before application, depth of penetration and operating environment of the structure.

### Materials and Methods

The experimental part of the study was carried out under laboratory conditions on heavy concrete specimens prepared from Portland cement CEM I 42.5N, quartz sand, crushed granite aggregate with a maximum particle size of 20 mm and potable water. A conventional structural concrete mix with a water–cement ratio of 0.50 was selected in order to simulate a material commonly used in civil construction and at the same time sufficiently sensitive to moisture transport in the near-surface zone.

After mixing, the concrete was placed into standard steel molds and compacted on a vibration table. The specimens were demolded after 24 hours and cured for 28 days under controlled laboratory conditions. After curing, the specimens were divided into three groups. The first group was retained as a control without any surface treatment. The second group was treated with a sodium-silicate-based impregnating composition intended to densify the surface layer. The third group was treated with an organosilicon hydrophobic impregnation intended to reduce capillary wetting and water intake.

Before application of the impregnating compounds, the concrete surfaces were dried to a stable condition and cleaned from dust and laitance. The compositions were applied by brush saturation until refusal. After treatment, the specimens were stored for an additional seven days to stabilize the modified surface layer before testing.

The following indicators were determined during the experimental program: average density, water absorption by mass, capillary water absorption within twenty-four hours, compressive strength and resistance to water penetration under pressure. Water absorption by mass was determined from the increase in specimen mass after saturation. Capillary absorption was assessed by partial immersion and periodic weighing. Compressive strength was measured by means of a hydraulic press according to standard laboratory procedures. Water impermeability was determined by stepwise pressure increase until visible seepage occurred on the opposite face of the sample.

The comparative design of the experiment made it possible to identify how the selected impregnating systems influence the transport of water and the mechanical behavior of hardened concrete under otherwise identical conditions.



## Results

The obtained experimental data showed that both types of impregnation had a positive effect on the waterproofing properties of concrete, although the character and magnitude of improvement differed depending on the chemical mechanism of the treatment.

The average density of all three groups remained close, which indicates that the base concrete composition and curing conditions were comparable. At the same time, clear differences were observed in water absorption and capillary uptake. The control specimens demonstrated the highest water absorption by mass, equal to 5.8%. After treatment with sodium silicate, this value decreased to 3.9%, while in the specimens treated with organosilicon impregnation it decreased to 2.8%. Therefore, the reduction compared with untreated concrete amounted to approximately 32.8% for the silicate system and 51.7% for the hydrophobic system.

A similar trend was observed for capillary absorption after twenty-four hours. The control group exhibited a capillary uptake of 1.72 kg/m<sup>2</sup>, whereas the value for the silicate-treated concrete decreased to 1.05 kg/m<sup>2</sup> and for the hydrophobized concrete to 0.64 kg/m<sup>2</sup>. This confirms that both treatments reduced the ability of water to migrate into the near-surface zone, while the organosilicon composition most strongly suppressed the capillary transport mechanism.

In terms of mechanical behavior, the sodium-silicate treatment produced a moderate strengthening effect. The average compressive strength increased from 38.6 MPa in the control group to 41.1 MPa in Group A. This may be associated with pore refinement and additional formation of dense hydration-related products in the treated layer. The organosilicon system also showed a slight increase in compressive strength to 39.4 MPa, but the effect was less pronounced because hydrophobization mainly changes the wetting properties of capillary walls rather than directly densifying the matrix.

Water impermeability grades also improved. The untreated control corresponded to W6, the silicate-treated specimens reached W8, and the organosilicon-treated specimens reached W10. Visual inspection after testing showed no peeling, brittle film formation or other evident surface defects, which indicates that the applied impregnations worked within the pore structure rather than as unstable superficial coatings.

**Table 1. Comparative performance of untreated and impregnated concrete**

Indicator	Control group (C)	Group A (silicate impregnation)	Group B (hydrophobic impregnation)	Effect
Average density, kg/m <sup>3</sup>	2385	2398	2391	Minor change
Water absorption by mass, %	5.8	3.9	2.8	Decreased
Capillary absorption after 24 h, kg/m <sup>2</sup>	1.72	1.05	0.64	Decreased
Compressive strength, MPa	38.6	41.1	39.4	Slight increase
Water impermeability grade	W6	W8	W10	Improved



## Discussion

The results obtained in the study confirm the working hypothesis that properly selected impregnating compositions are capable of substantially reducing water permeability in hardened concrete. At the same time, the mechanisms of action of the two systems are different, which explains the differences in measured indicators.

The sodium-silicate composition primarily acted as a densifying system. Because soluble silicates react with calcium hydroxide and other alkaline components of cement stone, they contribute to the formation of additional poorly soluble compounds and to partial blocking of capillary channels. This explains the reduction in both water absorption and capillary uptake together with the moderate rise in compressive strength. Such compositions can therefore be recommended where the task is not only waterproofing but also surface consolidation and wear resistance improvement.

The organosilicon system demonstrated the strongest influence on water transport indicators. Its effect is based mainly on hydrophobization of the pore walls. Once the capillary surface becomes water repellent, the driving force for capillary rise decreases sharply, and liquid water can no longer easily penetrate the treated zone. This explains why Group B showed the lowest water absorption and the highest water impermeability grade. From the engineering point of view, such materials are especially suitable for façades, basements, retaining walls, tunnel linings and other structures exposed to atmospheric moisture, splash water or capillary rise.

An important practical conclusion follows from the experiment: impregnation is especially useful when it is impossible or impractical to redesign the original concrete mix. For existing structures, the method can be applied during preventive maintenance or local repair campaigns. Compared with thick barrier coatings, it preserves the texture of the concrete surface, usually does not form a separate fragile film and can be used on geometrically complex surfaces.

At the same time, the method should not be considered universal. Its efficiency depends on substrate porosity, moisture content during application, crack width, depth of penetration and service environment. Wide cracks or strong hydrostatic pressure may require additional sealing systems or integral waterproofing measures. Therefore, impregnation should be included as one component of a broader durability strategy that also encompasses proper mix design, curing, crack control and drainage organization.

## Conclusion

The study makes it possible to formulate the following conclusions. First, the waterproofing properties of concrete are determined by the structure and connectivity of capillary pores through which water and dissolved aggressive agents enter the material. Second, surface impregnation is an effective technological method for reducing water transport in hardened concrete without changing the geometry of the element and without complicated reconstruction measures. Third, sodium-silicate impregnation decreases water absorption and capillary moisture uptake and additionally produces moderate strengthening of the surface layer. Fourth, organosilicon hydrophobic impregnation provides the most pronounced reduction in capillary water intake and the greatest increase in water impermeability. Fifth, the impregnation method is particularly promising for underground, hydraulic, transport and civil structures operating

under humid or aggressive conditions. Sixth, in engineering practice the specific impregnating system should be selected on the basis of service exposure, substrate condition and the balance between densification and hydrophobization effects.

Consequently, enhancement of concrete waterproofing properties by the impregnation method is a scientifically grounded and practically effective approach for increasing the operational reliability and service life of concrete and reinforced-concrete structures.

### References

1. Neville, A. M. Properties of Concrete. 5th ed. Harlow: Pearson Education, 2011.
2. Mehta, P. K., Monteiro, P. J. M. Concrete: Microstructure, Properties, and Materials. 4th ed. New York: McGraw-Hill Education, 2014.
3. Aïtcin, P.-C. Binders for Durable and Sustainable Concrete. London: CRC Press, 2008.
4. Basheer, P. A. M., Kropp, J., Cleland, D. J. Assessment of the durability of concrete from its permeation properties: a review. Construction and Building Materials. 2001. Vol. 15. No. 2–3. Pp. 93–103.
5. Hall, C. Water sorptivity of mortars and concretes: a review. Magazine of Concrete Research. 1989. Vol. 41. No. 147. Pp. 51–61.
6. Sabir, B. B. Transport properties of concrete and steel corrosion. Magazine of Concrete Research. 1997. Vol. 49. No. 179. Pp. 89–101.
7. Shi, X., Xie, N., Fortune, K., Gong, J. Durability of steel reinforced concrete in chloride environments: an overview. Construction and Building Materials. 2012. Vol. 30. Pp. 125–138.
8. Zhang, P., Wittmann, F. H., Zhao, T., Lehmann, E. Neutron imaging of water penetration into cracked steel reinforced concrete. Physics Procedia. 2015. Vol. 69. Pp. 88–95.
9. Ramachandran, V. S. Concrete Admixtures Handbook. 2nd ed. Park Ridge, NJ: Noyes Publications, 1995.
10. Bertolini, L., Elsener, B., Pedferri, P., Redaelli, E., Polder, R. Corrosion of Steel in Concrete: Prevention, Diagnosis, Repair. 2nd ed. Weinheim: Wiley-VCH, 2013.

