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# The influence of waterproofing additives introduced into the mass of fresh concrete on the on the durability feature of the hardened concrete

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**Abstract.** The constructions with fluid retention and storage in general, between which the water holds a significant weight, are permanently exposed of physical and mechanical actions of deposited agent, with the continuous manifestation of the exfiltration tendency, hereby the requirement of performance at tightness becomes essential. If the constructions that fulfill this role are realized of reinforced concrete, the tightness at fluid in general and at water in particular of the elements which compose the storage space is insured in a significant proportion by the waterproofing qualities of the structural concrete put in place. When the process of waterproofing concrete is clean and environmentally friendly and leads to improvement of initial physical- mechanical characteristics, represents an essential element in the combined approach of the performance requirements regarding the tightness and resistance condition. In this paper is presented a research study concerning the positive influence of waterproofing additive “Penetron” introduced into the fresh concrete mass used to realization of structural elements, with the role of storage and treatment of waste water, to mechanical characteristics of concrete after hardening.

## 1. Introduction

### 1.1. General aspects regarding the durability of the constructions

The period of time in which the construction provides normal operating conditions, in accordance with the function assigned to the design, represents the “anticipated service life” or the “projected service life”, which generically expresses the notion of durability.

By defining the notion of sustainability, this feature is attributed to the construction system, following the assumed development of the stages of conception, design and execution. In this approach, sustainability is the characteristic of a construction based on the performance requirements designed, materialized by an adequate execution and maintenance-repair works carried out properly and on time during the projected service life. Given the complexity of the construction of buildings as well as the diversity of operating or external environmental factors and their mode of action, the assessment of sustainability is a laborious problem, with a variety of variable elements, of limited knowledge, which influence the normal life span.



In this context, the evaluation of the lifetime of constructions is the result of a probabilistic approach, based on interpretations and processing of statistical data, depending on the multitude and variability of the considered characteristics.

Starting from the difficulty of directly determining the anticipated (projected) lifespan, this is evaluated in modern practice based on the performance characteristics attributed to the constructions to the design, in direct correlation with the predictable ones for the existing constructions, similar in terms of design and construction. The operating environment conditions, for which “in situ” checks and tests can be carried out, following the behavior in time and meeting the performance characteristics initially planned [1].

The durability of a construction is determined by a complex of factors, regarding:

- the design activity;
- the execution activity;
- the repair-maintenance-operation activity;
- the characteristics of the materials used and their evolution over time;
- operating environment conditions
- the action of external factors
- other aggressive actions

In this presentation, the characteristics of the materials used in the construction elements are an important factor in ensuring the durability characteristics under the conditions of the function to be performed.

Therefore, in the case of concrete constructions with a liquid retention and storage role, the performance requirement regarding the sealing is directly reflected by the characteristics of the materials used, between which the waterproofing solution occupies a special place.

### *1.2. General considerations regarding the action of waterproofing additives*

The permeability of the concrete is a physical characteristic that expresses the ability to penetrate the gases or liquids in its mass in the presence of a certain pressure difference.

Water penetration in concrete is determined by the hydrostatic pressure gradient, capillary suction, diffusion of water vapor and osmotic pressure.

Contrary to the physical characteristics regarding the permeability of the concrete, the water impermeability of the hardened concrete reflects its ability to prevent the ingress of pressurized water into its mass.

The requirement of impermeability is absolutely necessary in the case of the concrete used in the construction of water retention and storage constructions, specific to the constructions in the water supply and sewage systems of the waste water treatment stations, of the hydrotechnical, maritime constructions etc.

The reduced water permeability of the concrete is influenced by the compactness and existence of the pores, reflected by the composition (dosages, basic materials, and additives), the pouring technology and the protection after casting [2-4].

Additives, in general, are technical substances or products that are introduced into the concrete mass when preparing, for the purpose of the desired modification of the new characteristics, by specific physico-chemical mechanisms.

In the case of waterproofing additives, their introduction into the concrete composition, in preparation, favors the reduction or cessation of the phenomena of physical nature at the level of the matrix under the action of the liquid phase contained in the operating environment.

The physico-chemical mechanisms by which the impermeability of the concrete is ensured, without negatively influencing the mechanical and volume characteristics, are multiple, and can be synthesized according to the action of the additives as follows [5]:

- by forming colloidal compounds that produce clogging of pores and voids in the concrete mass;
- by reducing the A/C ratio, by changing the pore size and distribution;

- by the hydrophobization action on the cement granules, respectively by reducing the capillary ascension of the water;
- by training and favorable distribution of air in the concrete mass.

In this paper, the experimental studies performed are based on the action of the waterproofing additive Penetron admix, introduced into the mass of fresh concrete in a percentage of (0.8-1)% of the amount of cement, before casting, in the concrete mixer, and energy mixing for 15 min., according to figure 1.

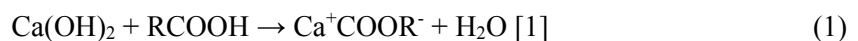


**Figure 1.** Introduction of the Penetron admix additive in the fresh concrete mass and homogenization of the mixture.

The waterproofing action of the Penetron admix additive is due to the multiplication of the crystalline component in the matrix and the filling of the pores in the concrete mass.

The Penetron admix waterproofing additive is supplied in powder form, having the mineralogical composition compatible with that of Portland cement, and in contact with water, the accentuated development of chemical reactions between the components of the additive and the hydration products of the cement with formation and multiplication of the chain is stimulated crystalline compounds.

The chemical reaction that occurs when the Penetron admix waterproofing additive is introduced into the fresh concrete mass, occurs according to the following generic mechanism [6]:



where  $\text{Ca(OH)}_2$  – calcium hydroxide contained in the mass of fresh concrete;  $\text{RCOOH}$  – stearate mixture contained in the Penetron admix waterproofing powder;  $\text{Ca}^+\text{COOR}^-$  – insoluble calcium stearate, the resultant component of the chemical reaction;  $\text{H}_2\text{O}$  – the water released from the chemical reaction.

The increase of the volume of the crystalline component of the concrete nature, after the introduction of the additive Penetron admix, gives to the hardened mixture waterproofing properties, which stop the penetration of water into its mass and recommend the use of the additive in the case of constructions with fluid retention and storage.

## 2. Description of experimental research

The experimental study aimed to highlight the influence of the Penetron admix waterproofing additive, introduced in the fresh concrete mass as a waterproofing solution, of two decanters with the role of retention and treatment of waste water resulting from the process of processing of animal waste, on the characteristics of durability of hardened concrete.

### 2.1. Analysis of the factors of influence of the sustainability characteristics

The experimental researches aimed to perform a comparative study on the physico-mechanical characteristics determined in the laboratory on ordinary concrete samples and concrete samples in the composition of which Penetron admix waterproofing additive was introduced and "in situ" on two reinforced concrete decanters. The experimental studies carried out in the laboratory on concrete samples of classes C20/25, C25/30, C30/37 and C35/45 aimed at:

- determination of compressive strength at 28 days;
- determination of the degree of impermeability to water and the penetration depth;
- analysis of the microstructure of the hardened concrete by optical microscopy.

The "in situ" experimental study aimed to determine the time of self-repair of the defects in the walls of the reinforced concrete decanters related to a wastewater treatment plant.

*2.1.1. Determination of compressive strength.* For having a clear image on the influence of the waterproofing additive Penetron admix introduced into the fresh concrete mass on the compressive strength of the hardened concrete, determinations were made on cubic-shaped test pieces, with a side of 150 mm, 28 days after making.

Laboratory determinations were performed on a number of 24 samples, made of concrete of the classes: C20/25, C25/30, C30/37, C35/45, of which 12 samples without a waterproofing additive and 12 tests with a Penetron admix waterproofing additive, introduced into the mass of fresh concrete at preparation, in the percentage of 0.85% of the quantity of cement.

The results obtained from the determinations made are presented in table 1.

**Table 1.** The values of compressive strength on concrete grades.

	Concrete class	Compressive strength (MPa)			Average compressive strength (MPa)	
		Sample 1	Sample 2	Sample 3		
<b>1</b>	Without the addition of waterproofing Penetron admix	C20/25	26.1	25.8	27.6	26.5
<b>2</b>		C25/30	32.7	32.5	33.7	32.96
<b>3</b>		C30/37	38.7	38.1	38.9	38.56
<b>4</b>		C35/45	46.8	47.5	46.7	47
<b>5</b>	With the addition of waterproofing Penetron admix	C20/25	26.4	26	27.8	26.7
<b>6</b>		C25/30	32.9	32.8	33.5	33.07
<b>7</b>		C30/37	38.5	38.5	38.9	38.63
<b>8</b>		C35/45	46.9	48.1	47.2	47.4

The interpretation of the table data shows close values of the compressive strength on concrete classes in the two variants of realization, with a slight increase, but not mechanically significant, for the samples with Penetron admix waterproofing additive.

This slight increase of the compressive strength for the samples made with concrete in which Penetron admix waterproofing additive was introduced in 0.85% of the cement quantity, is explained by the strengthening of the additional crystalline formations favored by the additive.

Therefore, the Penetron admix waterproofing additive introduced into the fresh concrete mass does not influence the class of the concrete, but it increases the compactness of its microstructure, by filling the pores with microcrystals generated by the Penetron admix waterproofing additive, thus reducing the transport phenomena in the concrete mass, respectively the improvement of the service life.

*2.1.2. Determining the degree of waterproofness and the penetration depth.* The water penetration resistance was determined on standardized concrete samples, classes C20/25, C25/30, C30/37, C35/45 under the specific working conditions for this type of test. The water penetration determination was performed at a pressure of 0.8 MPa, the results being presented in table 2.

**Table 2.** The depth of water penetration in the concrete sample.

	Concrete class	Depth of water penetration (cm) at working pressure of water 0.8 MPa			Average depth of water penetration (cm)	
		Sample 1	Sample 2	Sample 3		
<b>1</b>	Without the addition of waterproofing Penetron admix	C20/25	2.2	2.0	2.0	2.07
<b>2</b>		C25/30	2.0	1.7	1.7	1.8
<b>3</b>		C30/37	1.8	1.5	1.5	1.6
<b>4</b>		C35/45	1.4	1.4	1.3	1.37
<b>5</b>	With the addition of waterproofing Penetron admix	C20/25	1.7	1.8	1.7	1.73
<b>6</b>		C25/30	1.5	1.4	1.4	1.43
<b>7</b>		C30/37	1.2	1.2	1.2	1.2
<b>8</b>		C35/45	1.0	0.9	1.1	1

Following the table data, the following aspects are distinguished:

- the average values of the water penetration depth are less than 1.3 cm, in the case of concrete samples without the addition of waterproofing Penetron admix;
- the average values of the water penetration depth are less than 1 cm, in the case of concrete samples with Penetron admix waterproofing addition;
- the water penetration depth is dependent on the concrete class;
- the Penetron admix waterproofing additive introduced into the concrete mass by 0.85% of the amount of cement, reduces the water penetration depth, in the following percentages: 16.5% for C20/25; 21% for C25/30; 25% for C30/37; 27% for C35/45.

The beneficial aspects of the microstructure of the concrete generated by the increase of the crystalline formations in the matrix as a result of the introduction of the waterproofing additive Penetron admix, which fills the pores of gel and capillaries, reducing the porosity of the concrete and the capillary suction of the water, clearly reflects the improvement of the resistance to water penetration and the durability characteristics of the hardened concrete.

*2.1.3. Analysis of the microstructure of the hardened concrete by optical microscopy.* The compression-tested concrete specimens, shown in figure 2, were prepared by splitting them into smaller fragments for analysis of microstructure by optical microscopy.



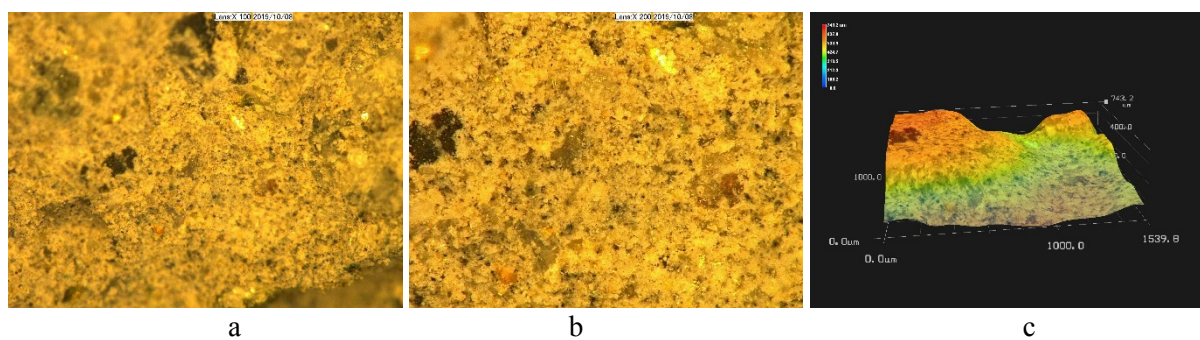
**Figure 2.** Compression-tested samples, waiting for optical microscopy.

The optical analysis of the hardened concrete fragments was carried out within the Research Institute for Sustainable Development at the Transilvania University of Brasov, using the Keyence VHX600 digital microscope, with a 54 MP video camera and three CCD sensors, which provide internal focusing and magnification from 20x to 200x.

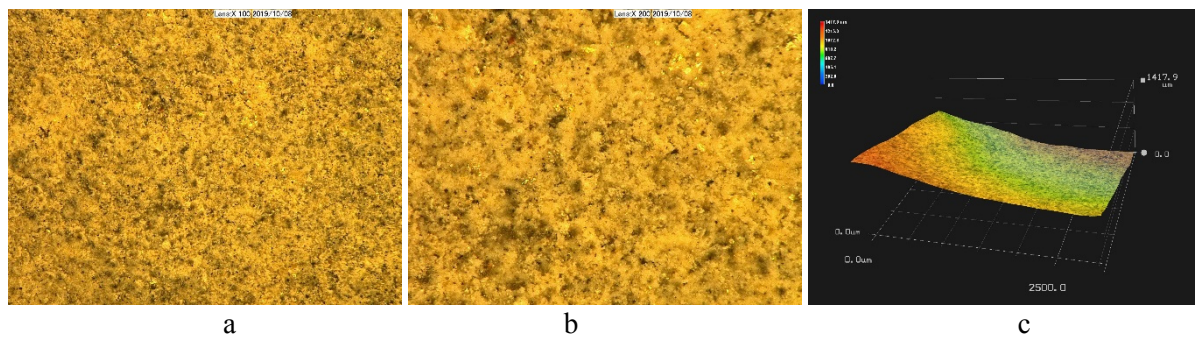
The hardened concrete fragments were extracted from the compression test samples, classes C20/25, C25/30, C30/37, C35/45, respectively 12 pieces without a waterproofing additive and 12 pieces with a Penetron admix waterproofing additive.

The optical analysis carried out aimed at highlighting, in comparative aspect, the microstructure of the concrete, on concrete classes, without and with Penetron admix waterproofing additive, introduced into the fresh concrete mass.

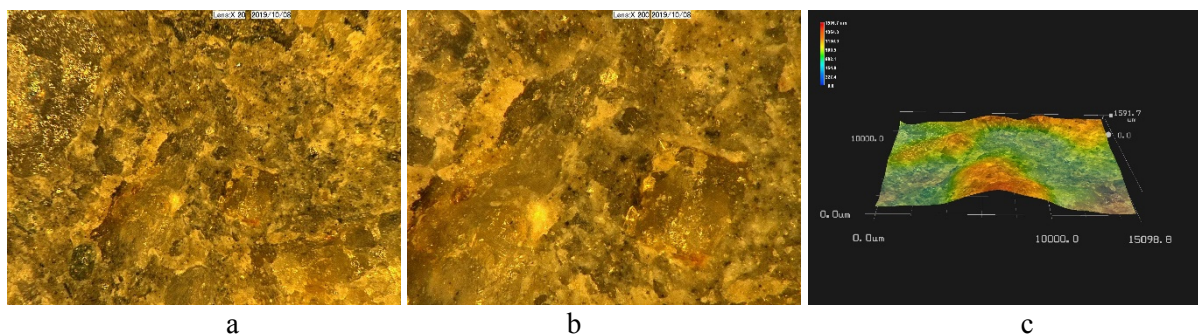
Representative aspects regarding the concrete texture of the analyzed samples are presented in figures 3, 4, 5 and 6, where the microscopic images are focused and magnified by 200x.



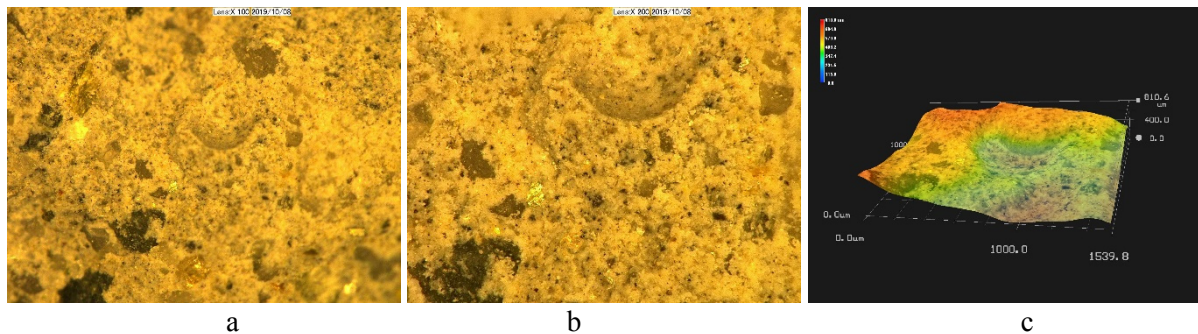
**Figure 3.** Microscopic images of the C20/25 concrete test specimen: a – without waterproofing additive; b – with Penetron admix additive; c – 3D representation.



**Figure 4.** Microscopic images of the C25/30 concrete test specimen: a – without waterproofing additive; b – with Penetron admix additive; c – 3D representation.



**Figure 5.** Microscopic images of the C30/37 concrete test specimen: a – without waterproofing additive; b – with Penetron admix additive; c – 3D representation.



**Figure 6.** Microscopic images of the C35/45 concrete test specimen: a – without waterproofing additive; b – with Penetron admix additive; c – 3D representation.

The microscopic images made on the hardened concrete specimens highlight the following aspects:

- the texture of the concrete prepared with waterproofing additive Penetron admix is more uniform and compact for all classes of concrete, compared to that of the concrete of the same class, without waterproofing additive;
- concrete samples with a waterproofing additive highlight a fine particle agglomeration in the matrix of the hardened concrete, compared to the internal structure of the samples without a waterproofing additive;
- concrete samples with a waterproofing additive show a lower internal porosity microstructure, compared to the samples made of concrete without a waterproofing additive.

All the illustrative aspects indicated highlight the beneficial role of the Penetron admix waterproofing additive, for all classes of concrete, on the durability characteristics of the hardened concrete.

*2.1.4. The self-repair time, in situ, of the defects in the hardened concrete structure.* Starting from the use of the concrete with waterproofing additive Penetron admix to the realization of the elements that are part of the structural composition of the constructions with the role of retention and storage of the liquids, the aim was to highlight the time of self-repair of the cracks due to concrete contraction in the first days after the casting.

The phenomenon of self-repair refers to contraction cracks, which occur frequently in the case of concrete elements.

The observations were made in situ on the walls of two decanters of reinforced concrete with the role of storage and treatment of waste water, in a unit for processing animal waste.

The results showed that after 28 days the process of water infiltration through cracks is reduced by about 50 % compared to the initial situation [7].

### 3. Conclusions

Experimental researches regarding the influence of the waterproofing additive Penetron admix from the mass of the fresh concrete on the durability characteristic on the reinforced concrete, have led to the following conclusions:

- the Penetron admix waterproofing additive introduced into the fresh concrete mass does not influence the concrete class. The increase of the compressive strength is insignificant, below 1%, but it increases the compactness of the microstructure by filling the gel and capillary pores with newly formed crystals, reducing the phenomena of transport in the concrete mass of the degrading agents.
- the depth of water penetration in the concrete mass is reduced, according to its class, as follows: 16.5% for C20/25, 21% for C25/30, 25% for C30/37 and 27% for C35/45;
- the analysis of optical microscopy shows a microstructure of the concrete in which Penetron admix waterproofing additive was introduced more uniform and compact, compared to the one of the concrete without waterproofing additive;

- the phenomenon of multiplying the crystalline formation following the hydration reactions that take place after mixing the additive Penetron admix with water ensures, in time, the self-repair of the internal cracks due, in general, to the contraction of the concrete.

The results of the experimental researches highlight by the analyzed factors the increase of the durability characteristic of the reinforced concrete in which was introduced waterproofing additive Penetron admix, with more than 10%, compared to the same class of concrete without additional waterproofing.

The solution of waterproofing of concrete by introducing in its mass the waterproofing additive Penetron admix is practicable and friendlier with the environment compared to the classic version of waterproofing, a relevant image in this sense is that of figure 7, which represents a treatment station of waste water from an animal waste processing unit.



**Figure 7.** Wastewater treatment station in operation.

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