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COMPARATIVE STUDY OF PRACTICAL SOLUTIONS CONCERNING WATER TIGHTNESS OF TWO REINFORCED CONCRETE DECANTERS

I. TUNS[1] F-L. TAMAS[1]

Abstract: *For the constructions with the role of retention and liquid storage, the requirement of water permeability performance under the specific operating conditions becomes fundamental. The fulfillment of this requirement is ensured by a complex analysis process concerning the design and construction of the system, among which the waterproofing solution (s) are a priority. This paper presents a case study on the comparative analysis of two practically possible solutions to waterproof the reinforced concrete decanters belonging to a wastewater treatment plant from a waste processing unit of animal origin. Comparative analysis is based on technical, economic, sustainability and time criteria.*

Key words: *admixture, waterproofing, concrete, permeability, decanters, durability, hydration.*

1. Introduction

Durability represents one of the key characteristics of concrete that has led to its widespread use. Durability of hydraulic-cement concrete is determined by its ability to resist weathering action, chemical attack, abrasion, or any other process of deterioration [1].

According to the ASTM C125-16, an admixture is defined as a material other than water, aggregates, cementitious material, and fiber reinforcement that is used as an ingredient of a cementitious mixture to modify its freshly mixed, setting, or hardened properties and that is added to the batch before or during its mixing [2].

Chemical admixtures are primarily water-soluble substances used to enhance the properties of concrete or mortar in the plastic and hardened state. These benefits include increased compressive and flexural strength at all ages, decreased permeability and improved durability, corrosion reduction, shrinkage reduction, initial set adjustments, increased slump and workability, improved pumpability, finish and finishability, rheology modification, improved cement efficiency, alkali-silica reaction (ASR) reduction, and concrete mixture economy [3].

[1] Faculty of Civil Engineering, *Transilvania* University of Braşov.

1.1. General presentation data

The comparative analysis presented in the paper refers to two practically waterproofing solutions possible to be applied to the ”Decanter of compensation” and ”Decanter for biological neutralization” from the technological flux line in the process of waste water treatment from a unit for processing / neutralization / incineration byproducts and animal waste. The site plan for those two decanters from the technological flux line is presented in Figure 1 [4,5].

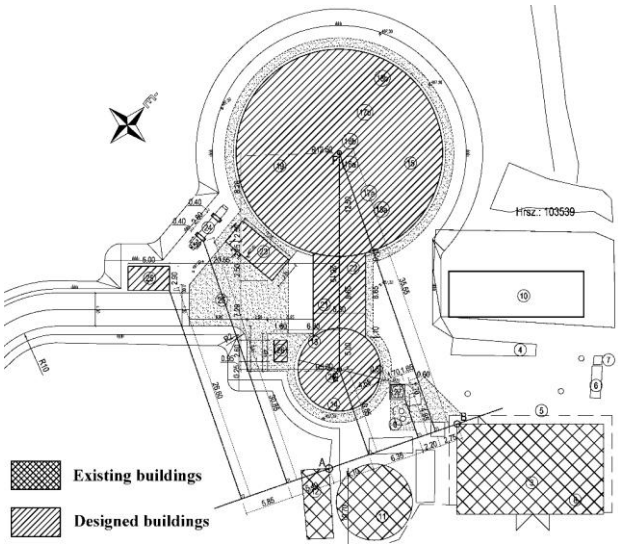

Fig. 1. *General site plan of technology line – Wastewater treatment plants*

The common structural elements of the two decanters with the role of retention and treatment of wastewaters refer to [5]:

- 35 cm thick raft foundation;
- reinforced concrete walls of 35 cm thick, fixed on the raft foundation.

The requirement for waterproofing of the decanters is ensured in the design project by the C35/45 XC4XD2XF1XA2 CEMIIA-S42.5R Cl0.2% concrete composition, without specifying the type of waterproofing additive required to achieve the degree of impermeability P12 and G150 freeze-thaw degree.

Taking into account these data, two possible solutions were considered in the comparative analysis for choosing the optimal solution for waterproofing:

- mass waterproofing with the Penetron Admix additive;
- external waterproofing by applying a rigid layer of cement mortar with Penetron Admix on the inner face.

1.2. General presentation of waterproofing solutions

The waterproofing solutions analyzed are suitable for the technological flow conditions, without requiring additional protection works against mechanical or

chemical actions, with stiffness characteristics similar to or close to the reinforced concrete structural element.

• Waterproofing solution in the concrete mass

In this variant, the waterproofing solution consists of introducing into the mass of fresh concrete, prior to casting, of a Penetron Admix type additive, compatible with the mineralogical nature of Portland cement.

The solution is easy to apply, consisting of the following stages [7]:

- mechanical blending of Penetron Admix powder in water for 30-40 seconds, the dosage being 1 kg Penetron Admix in 1.28 l water;
- adding the mixture to concrete mixer and blending about 1 min / 1 mc concrete;
- pouring concrete by specific technological processes, including vibration;
- concrete treatment after pouring, watering and protection against solar heat for 5 days.

After mixing the Penetron Admix additive with water, hydration and hydrolysis reactions are initiated and produced with the formation of gels and crystalline compounds similar to Portland cement.

The chemicals from the Penetron Admix additive activates and accelerates the multiplication of the crystalline component that diffuses into the concrete structure by filling the inner pores and interstitial spaces, blocking the circulation / migration of water and water vapor, thereby making it waterproof. The hydration process takes time, with maximum multiplication occurring in the first 3-4 weeks.

• External waterproofing method

It is a classic process, mainly used for the waterproofing of drinking water tanks or other liquid storage containers. The solution is suitable for reinforced concrete constructions and consists in the realization of a stiff impermeable layer on the liquid-contacting side having rigidity close to that of the support. The steps to follow are:

- preparing and priming the support layer;
- manual / shotcrete application in layers - in the case of vertical elements – respectively one layer in the case of horizontal elements of a cement mortar with the maximum size of aggregates of 8 mm, in which Penetron admix is introduced;
- providing a wet environment for 7 days by spraying with water;
- making leak test for the additional layer after reaching the designed compressive strength.

2. Comparative Analysis Study of Waterproofing Solutions

The comparative analysis of the waterproofing solutions concerned:

- evaluation of physical-mechanical characteristics;
- evaluation of cost/m^2.
- evaluation of time-consuming.

2.1. Assessment of The Physical-Mechanical Characteristics

The study focused mainly on the certification of the waterproofing solution in the concrete mass, for practical application, where there is little technical data on the influence of the Penetron Admix additive on the fresh and hardened mixture compared to the external waterproofing solution with good performance over time.

For the waterproofing solution in the concrete mass, the physical-mechanical characteristics of the hardened mixture was analyzed, aiming to certify the use of this method under the operating conditions of the decanters integrated in the technological flux line of a wastewater treatment plant, respectively [7]:

- compressive strength of concrete with addition of Penetron Admix additive;
- water permeability;
- autogenous repair of cracks.

• Compressive strength

Determination of compressive strength of concrete with addition of Penetron Admix waterproofing additive (1 % of cement quantity) at different ages (7 days, 14 days, 28 days) aimed at assessing the influence of the additive on this characteristic. The specimens were taken from a C35/45 class concrete, in the recipe version, with and without waterproofing admixture, kept and tested under standardized conditions.

The results of the determinations are summarized in Table 1.

Compressive strengths of the concrete, class C35/45 Table 1

Sample dimensions, [mm]		150x150x150								
Age of concrete at test time		7 days			14 days			28 days		
Sample number		1	2	3	1	2	3	1	2	3
Compressive strength, [N/mm^2]	**Concrete without waterproofing admixture**	35.7	34.5	34.9	38.7	38.9	38.7	45.7	46.5	46.1
	Concrete with waterproofing admixture	34.2	34.7	35.5	38.5	38.9	38.8	46.5	45.9	46.2
Average compressive strength, [N/mm^2]	**Concrete without waterproofing admixture**	35.03			38.8			46.1		
	Concrete with waterproofing admixture	34.8			38.7			46.2		

It can be noticed that the compressive strengths of concrete are not influenced by the Penetron Admix waterproofing additive introduced into the mass of fresh concrete in a percentage of 1 % of the amount of cement.

- **Water permeability**

Experimental determination was made on concrete with waterproofing additive Penetron Admix samples, exposed on one side to a hydrostatic pressure of 0.5 N/mm^2. Samples were taken at the frequency indicated by norms [6]. Aspects regarding the influence of the additive on the wetted surface evolution of the samples at different time periods are presented in Figure 2 to 5.

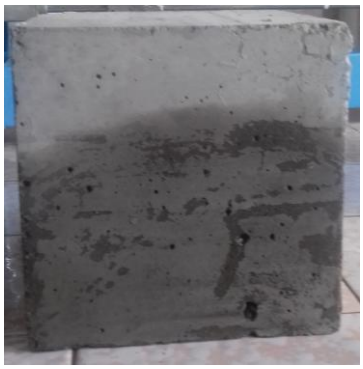

Fig. 2. *The exterior face of the sample after 7 days*

Fig. 3. *The exterior face of the sample after 14 days*

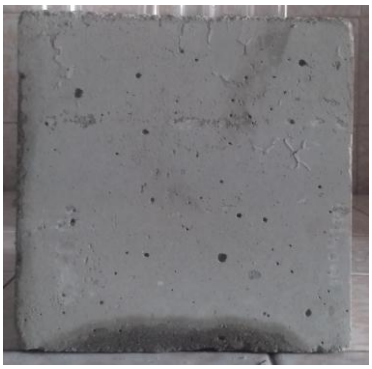

Fig. 4. *The exterior face of the sample after 21 days*

Fig. 5. *The exterior face of the sample after 28 days*

The experimental results on the penetration depth of the sample are shown in Table 2.

The evolution over time of the penetration depth of the sample Table 2

Hydrostatic pressure	0.5 N/mm^2											
Depth of water penetration, [mm]	7 days			14 days			21 days			28 days		
	22.5	22.2	23.4	17.2	16.8	16.5	13.1	12.1	12.5	10.7	10.8	11.2
Average penetration depth of the water, [mm]	22.7			16.8			12.6			10.9		

The process of multiplying the crystalline component of the Penetron Admix additive mass as a result of hydration and hydrolysis reactions occurs at maximum intensity within the first 3-4 weeks of mixing with water and introducing it into the fresh concrete composition. The complete stopping phenomenon of water penetration on the outer face of the specimen occurs after a maximum of 4 weeks, in the absence of execution defects. The diffusion of crystals generated by the Penetron Admix additive composition following hydration and hydrolysis reactions in the pores and interstitial spaces of the concrete matrix occurs relatively uniformly in all directions.

• Autogenous repair of cracks

The process of self-repairing of cracks by the autogenous phenomenon occurs as a result of hydration and hydrolysis reactions of the mineralogical components of Portland cement. Experimental tests revealed that the autogenous crack repair process is more pronounced in the case of concrete with Penetron Admix waterproofing additive compared to the same conventional concrete class. Thus, the water infiltration process, in cracks, after 28 days decreased by about 52 % for the concrete waterproofed with Penetron Admix, respectively 26.5% in the case of concrete without a waterproofing

additive. For the external waterproofing solution, the attached waterproof mortar layer creates a rigid mechanical barrier against water or liquid products whose waterproofing properties have been verified over time, being a practical process for reinforced concrete elements. In this context it is considered in the comparative analysis that the physical-mechanical characteristics presented for the previous solution are fulfilled.

2.2. Evaluation of the execution cost

The structure of the waterproofing solutions presented in Chapter 1 led to a cost/m^2 of 55.84 euro/m^2 for waterproofing solution in the concrete mass and 58.30 euro/m^2 for external waterproofing solution. The cost price/m^2 area is relatively close for the two variants, sensibly lower for the mass waterproofing solution, but with the advantage of intervening for repairs in the presence of pressurized water. For both solutions were also considered the possible remedial works in quantum of 20 %, 0.20 m^2 respectively.

2.3. Evaluation of the execution time

The structure of the waterproofing solutions described in Chapter 1 leads to the following execution times: 2.12 h/m^2 for waterproofing solution in the concrete mass and 5.54 h/m^2 for external waterproofing solution.

We can notice that waterproofing solution in the concrete mass with the Penetron Admix additive leads to a shorter execution time.

3. Conclusions

The comparative study carried out on the two waterproofing solutions of reinforced concrete decanters with the role of retention and wastewater treatment can be summarized in Figure 6, where S1 indicates the solution of waterproofing in the concrete mass and S2 the external waterproofing method.

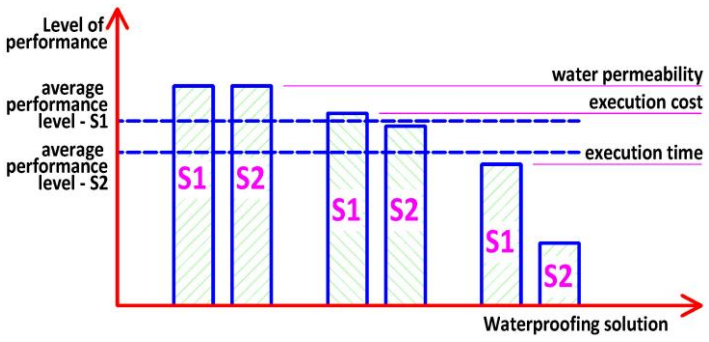

Fig. 6. *The performance levels of analyzed waterproofing solutions*

Some of the main conclusions can be formulated as follows:

- both solutions ensure the fulfillment of the water permeability performance requirements;

- the solution of waterproofing in concrete mass eliminates the possibility of degradation over time of the rigid waterproofing layer attached on the inner faces of the walls and on the top of the raft foundation;
- the external waterproofing solution provides increased thickness to the concrete cover of the reinforcements;
- the solution of waterproofing in concrete mass leads to a lower cost, a much shorter execution time and ensures the possibility of intervention for defect repair, even in the presence of pressurized water.

In the context of the presented, the waterproofing solution in the concrete mass becomes more advantageous compared to the external waterproofing solution.

The wastewater decanter in-service can be seen in Figure 7.

Fig. 7. *The wastewater decanter in-service*

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