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Modern technical solution of water tightness of reinforced concrete decanters. Case study

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Abstract. For reinforced special constructions with liquid storage roll, the performance exigencies concerning water tightness is essential. If the storage liquids represent potential sources of environmental pollution, the condition of removing external leaks is fundamental. This paper presents the case of the decanters of liquid residual products, resulting from the technological flow of processing animal proteins, employed in a wastewater treatment plant. The exigencies of water tightness performance of the reinforced concrete decanters are ensured by means of a modern, eco-friendly solution, based on the mass waterproofing of fresh concrete. This solution ensures water tightness without the need for any other protection works or external waterproofing, and any corrections can be applied even in the presence of water.

1. Introduction

1.1. General presentation elements

The modernization and the greening of the technological line related to a unit of processing / neutralization / incineration of by-products (not for consuming) and of animal waste in Brasov area led to the inclusion in the investment plan of the “Waste Water Treatment Plant” as in figure 1.

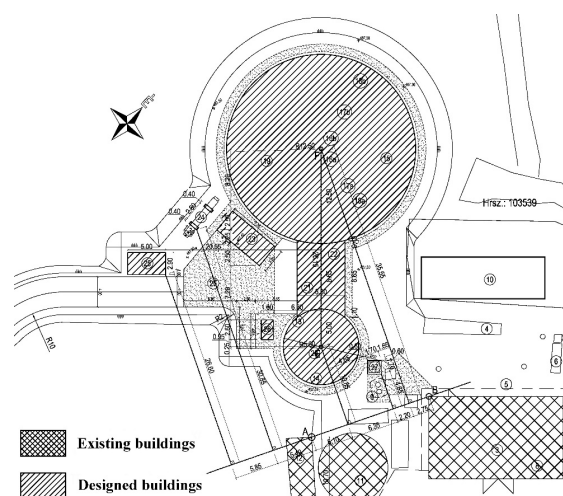


Figure 1. Wastewater treatment plants site plan.

The works related to the proposed investment of SC Protan SA Codlea refer to the sewage treatment line and consist, among other things, in the intercalation of two reinforced concrete collectors, one with the role of compensation, industrial accident, decantation, and the other with the role of biological neutralization of the compounds from the waste water.

The formwork plan and the corresponding section A-A of the biological decanter are presented in figure 2 and figure 3, respectively.

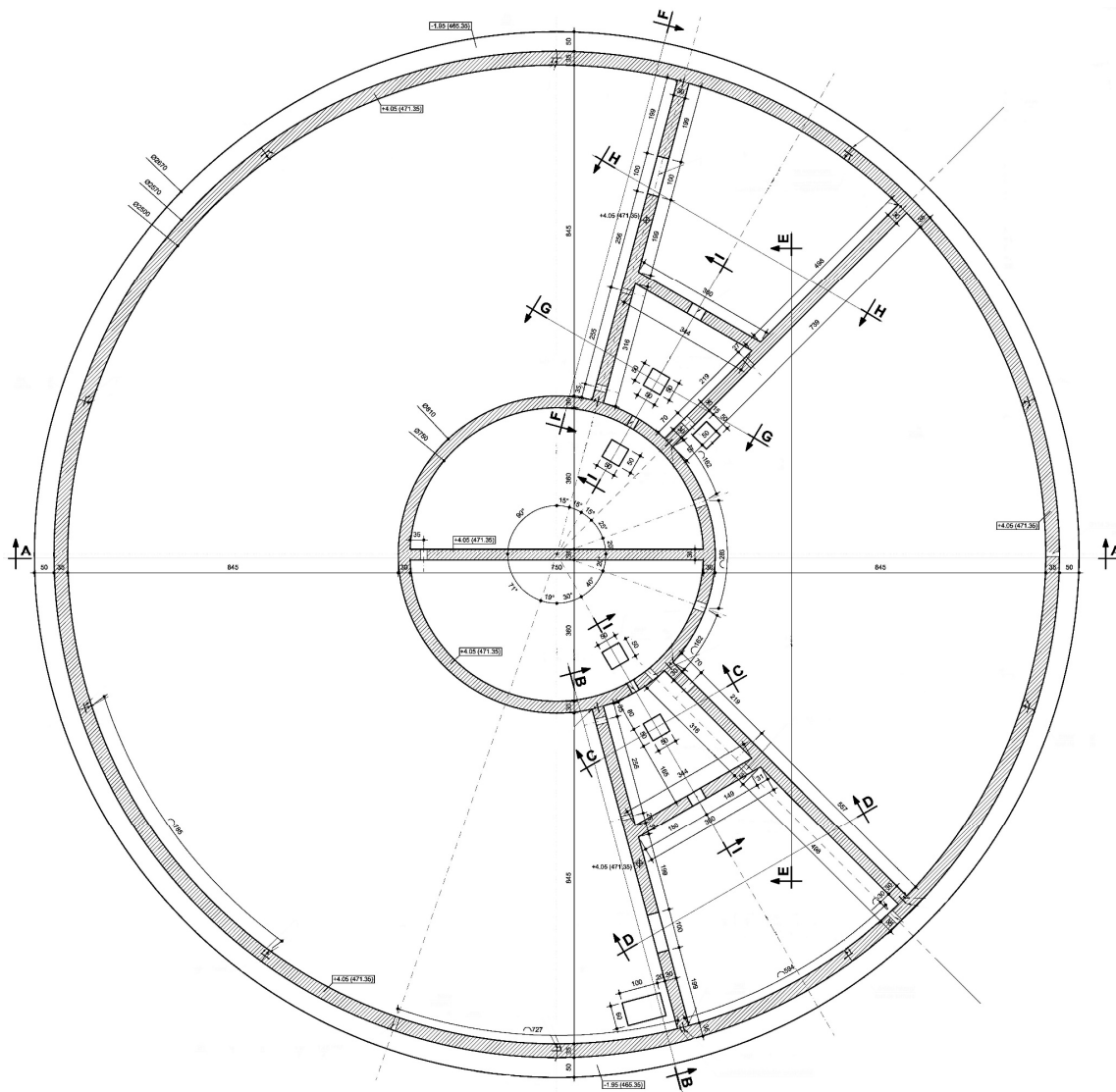


Figure 2. Formwork plan of the biological decanter.

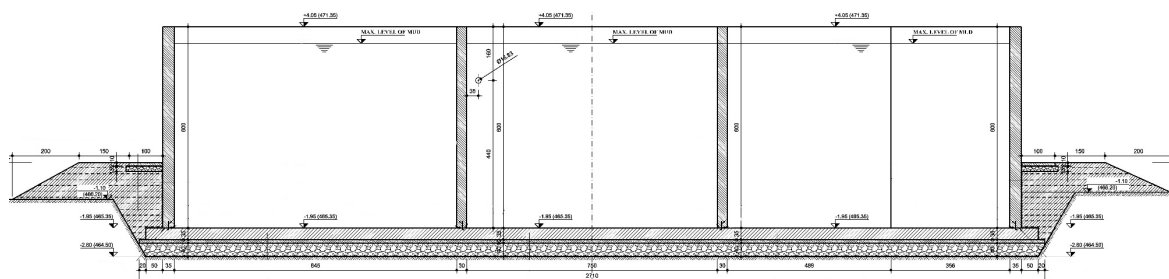


Figure 3. Section A-A corresponding to the biological decanter.

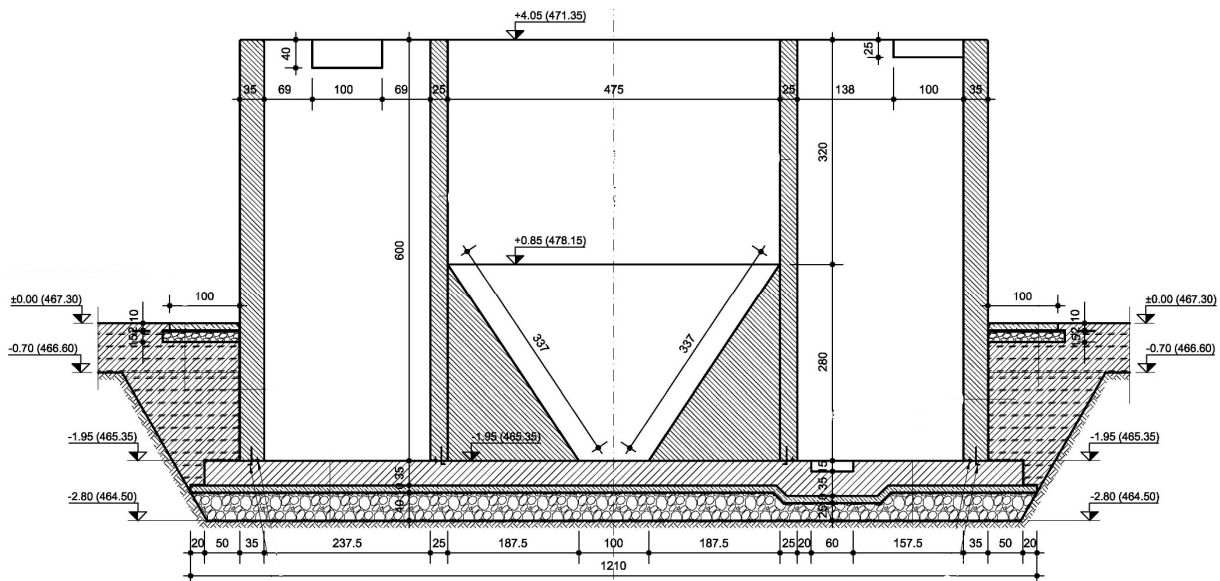


Figure 5. Section A-A corresponding to the compensation decanter.

1.2. Water tightness elements

According to the designed function, the two decanters need to ensure the storage and treatment of the wastewaters resulting from the technological process, in order to bring them to the quality parameters corresponding to the specific environmental requirements.

In this respect, all compartments for the two decanters must meet the water permeability performance requirements [1].

The design project contains specifications on the characteristics of the concrete used for the raft foundation and the walls, namely C35/45 XC4XD2XF1XA2 CEM IIA-S 42.5R C10.2% D16 S4, degree of impermeability P12, waterproofing additive, G150 freeze-thaw degree [2].

Without specifying the type of waterproofing additive, as this falls into the contractor's responsibility, thorough investigations have been made in this regard, aiming at identifying a product compatible with the type of cement used. This product, recommended by the positive experiences of similar works, must ensure the possibility of repairing defects after pouring, even in wet conditions.

Having a practical experience of previously using Penetron products for waterproofing the basement of a building, under the hydrostatic pressure water conditions [3], this technology was chosen, supported by the following technical and economic factors:

- Penetron powdered products are part of the clinker mineralized binder, which is hydrated in the presence of water, with the abundant multiplication of the crystalline component, thus being compatible with the Portland cement used in the preparation of concrete;
- the hardening process occurs in the presence of moisture;
- crystals resulting from hydration reactions have high penetration capacity in the mass of concrete, thus ensuring pore filling;
- it is added into the concrete mixer with about 15 minutes before pouring;
- it does not require additional works to those normally provided for the pouring operation and follow-up protection of the concrete (wetting and sun protection);
- it provides relatively easy conditions for repair interventions of the defects, in the presence of moisture and water under hydrostatic pressure;
- it does not require distinctly working time for waterproofing decanters;
- it does not require additional or special protection works on the structural elements;
- it has no negative impact on the environment.

For the case study, the following products were selected:

- Penetron Admix – added to the fresh concrete;
- Penetron, Penecrete mortar, Peneplug and Penetron plus, to repair defects after concrete pouring.

2. Technological description of the applied method

2.1. Mass waterproofing of fresh concrete

Based on the concrete characteristics specified in the design project, which provides, in addition to the mechanical characteristics required by the construction importance and destination, a high level of water tightness under a severe exploitation regime in terms of aggressive factors for concrete, and taking into account the considerations outlined in chapter 1, paragraph 1.2, the chosen method to waterproof fresh concrete was that by introducing Penetron Admix into its mass.

The technical instructions, the documentary material provided by the representative of the company selling Penetron products, displayed on the technical information networks were thus taken into account.

At the same time, in addition to the waterproofing requirement, we have also aimed at developing the process of evaluation / explanation the experimental data obtained following the application of the mentioned procedure, with the purpose of formulating valid conclusions for any further design and execution of similar works.

The Penetron Admix additive was inserted into the mass of fresh concrete directly into the concrete mixer, as shown in figure 6, followed by at least 15 minutes of mixing before pouring, with the following percentages of the amount of cement:

- 0.8% of the amount of cement for raft and two wall plots;
- 0.85% of the amount of cement for two wall plots;
- 0.90% of the amount of cement for two wall plots;
- 0.95% of the amount of cement for two wall plots;
- 1.0% of the amount of cement for two wall plots.



Figure 6. Inserting the Penetron Admix additive into the mass of fresh concrete with at least 15 minutes before pouring.

Pouring concrete into the decanters' walls, on predetermined design plots, was made with the purpose of limiting the opening of cracks from shrinkage and the amount of additive introduced into the fresh concrete complied with the recommendations contained in the technical instructions for use of the product. For each concrete pouring batch samples were taken at the frequency indicated in the norms provisions [4]. Pouring the concrete and its follow-up protection was done in accordance with the technical norms specific to these categories of works.

2.2. Waterproofing testing and correcting the noticed defects

28 days after pouring the last wall plot and sealing the technological pipe holes, the decanters were filled with water in order to perform the tightness test [5]. The water tightness test revealed the existence of some wall areas with a high level of moisture, generally located at the spacers used to ensure the thickness of the concrete cover layer of the reinforcements, at the joint with raft foundation, or in the pouring defects as presented in figures 7 and 8.



Figure 7. Areas of excessive humidity or leakage at the wall-raft foundation joint.



Figure 8. Areas of excessive humidity or leakage on wall.



Figure 9. Removing wall defects with Penecrete waterproofing additive.



Figure 10. Removing wall defects with Peneplug waterproofing additive.

The moisture spots on the wall, which were all due to the existence of pores interconnected from the concrete mass or to minor pouring defects, have disappeared within 3-14 days as a result of obstructing the formed spaces by depositing the crystals generated by the Penetron Admix additive in the presence of water. For the rest of the defects, they were opened, cleaned, deepened and repaired as appropriate:

- by brushing the emulsion of Penetron in water, ratio 5-2 and closing by pressing the mortar obtained from the mixture of Penetron powder with water, ratio 4-2, in the case of water without hydrostatic pressure, as indicated in figure 9;
- by vigorous pressing in the prepared hole of the mixture obtained from Penepug powder and water, in the case of water with hydrostatic pressure, according to figure 10.

Following the remediation procedures listed, the water tightness test was successfully performed for both decanters, currently in operation, as can be observed in figure 11.



Figure 11. The wastewater treatment plant in-service.

2.3. Processing and interpretation of experimental tests

The conducted experimental tests aimed at highlighting the following aspects:

- optimizing the consumption of Penetron Admix waterproofing additive inserted in the mass of fresh concrete, subject to the dosage indicated in the technical instructions [6];
- the influence of waterproofing additive dosage on the concrete class;
- the closing time of the pore from hardened concrete due to the crystals generated by the Penetron Admix additive, in the conditions of total immersion on one side of the wall.

Optimizing the consumption of Penetron Admix waterproofing additive inserted in the mass of fresh concrete. To optimize the dosage of a waterproofing additive, a multicriteria analysis was conducted based on:

- the percentage of wetted concrete surfaces after the water-tightness test, due to internal causes (interconnected capillary pores, entrapped air pores etc.), with the exception of execution defects;
- the percentage of self-repaired surfaces during water-tightness tests;
- the ability of crystals generated by the Penetron Admix additive to diffuse and penetrate in depth, highlighted by X-ray diffraction on concrete samples taken on site;
- the percentage of wetted surfaces remaining after self-repairing;
- the price/m² of the wall, including the costs of repairing water infiltrations.

Centralized data on the considered areas, the percentage of wet surfaces, repairs and costs are presented in table 1.

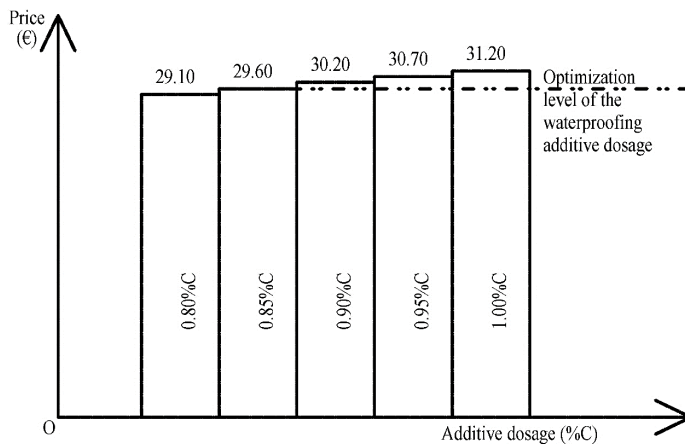
Table 1. Data of wet surfaces percentage / pouring plots / costs.

	Penetron Admix dosage ^a	Plots number	Plot surface [m ²]	Wetted surface [m ²]	Percentage of wetted surface [m ²]	Self-repaired wetted surface [m ²]	Repaired surface [m ²]	Price m ² /wall €
1	0.80% · C	2	130.3	2.30	1.76	1.70	0.06	29.10
2	0.85% · C	2	130.3	2.20	1.68	1.65	0.03	29.60
3	0.90% · C	2	130.3	2.15	1.65	1.63	0.02	30.20
4	0.95% · C	2	130.3	2.12	1.62	1.60	0.02	30.70
5	1.00% · C	2	130.3	2.12	1.62	1.60	0.02	31.20

^a Percentage related to cement quantity, C.

Regarding repairing costs, the data reveal insignificant differences in the doses of analyzed waterproofing additive.

The multicriteria analysis based on the above-mentioned parameters recommends variant no. 2, which leads to a cost difference of 1.6 eur/sqm, compared to variant no. 5, and provides similar quality requirements, as shown in figure 12.

**Figure 12.** The level of optimization for the waterproofing additive dosage.

The influence of Penetron Admix waterproofing additive on the concrete class. The results presented in table 2 show that the Penetron Admix waterproofing additive introduced into the mass of fresh concrete does not influence the concrete class, determined on the basis of the compressive strength obtained on 150 mm side cubic samples, kept under standardized conditions and tested at 28 days.

Table 2. Results on concrete samples taken on site.

	Sample data	Concrete class	Object	Compressive strength, $f_{ck,cub}$ [N/mm ²]	Outside temperature [°C]
1	05.07.2017	C35/45	Compensation decanter. Raft	45.11	26
2	05.07.2017	C35/45	Compensation decanter. Raft	49.70	28
3	11.07.2017	C35/45	Biological decanter. Raft	45.24	29
4	11.07.2017	C35/45	Biological decanter. Raft	46.30	27
5	03.08.2017	C35/45	Compensation decanter. Walls	45.42	29
6	10.08.2017	C35/45	Compensation decanter. Walls	45.66	29
7	25.08.2017	C35/45	Biological decanter. Walls	50.58	26
8	14.09.2017	C35/45	Biological decanter. Walls	45.21	22
9	20.09.2017	C35/45	Biological decanter. Walls	45.24	22
10	26.09.2017	C35/45	Biological decanter. Walls	45.21	19
11	28.09.2017	C35/45	Biological decanter. Walls	45.33	16

The closing time of the pore from hardened concrete due to the crystals generated by the Penetron Admix additive, in the conditions of total immersion on one side of the wall. The on-site investigation, conducted visually and by polls, has highlighted that areas where moisture spots were due to materials structure, except for execution mistakes, have self-repaired (disappeared) over a period of 3-14 days by diffusing and depositing the crystals generated by the Penetron Admix additive in the interior pores. This finding applies to all areas of the walls, regardless the dosage of the additive applied.

3. Conclusions

For the case study, the results of the interpretation and processing of the experimental data lead to the formulation of the following conclusions with validity for other municipal and public constructions, made of reinforced concrete, and meant for the storage of liquids:

- the mass concrete waterproofing solution with the Penetron Admix additive ensures that watertightness requirements are met without requiring additional protection or finishing work;
- Penetron Admix waterproof additive is compatible with Portland Cement;
- the optimization of the waterproofing additive dosage ranging within the manufacturer's recommended limits ensures a lower cost price with 1.6 eur per square foot compared to the upper limit of the range, under similar quality conditions;
- the insertion of Penetron Admix waterproofing additive in the fresh concrete mass does not influence the compressive strength;
- the closing time of all internal pores from the concrete mass after the total immersion of one face of the wall is two weeks.

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