EXPERIENCES IN TESTING OF CONCRETE FOR RESISTANCE TO WATER PENETRATION DURING CONSTRUCTION OF WWTP IN BIHAĆ

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Summary: *Water tightness defines the resistance of concrete structures to the penetration of water under specific pressure. Since hydrotehnical structures are mainly made of reinforced concrete and are used for water retention, these facilities must be watertight, so special attention is paid to the concrete mix design, including admixtures. Thus, satisfying this criteria was unavoidable during the design and construction of the Wastewater Treatment Plant in Bihać, as a part of the Project for Collection and Treatment of Waste Water. Consequently, testing of water resistance of concrete was conducted according to EN 12390-8:2010, and goal of this paper is to present this experience through data processing and test results.*

Keywords: *Water resistant concrete, Testing, Concrete Quality control, Waste Water Treatment Plant in Bihać*

1. INTRODUCTION

The project for design and construction of the Wastewater Collection and Treatment Plant in Bihać is divided into two parts:

1. Construction of sewerage pipeline – Component 1 and
2. Construction of Waste Water Treatment Plant – Component 2.

Waste Water Treatment Plant (WWTP) is a group of 25 facilities designed for purpose of purification of waste water that comes from sewerage pipeline for equivalent of 55,000 citizens and, at the end, flows into recipient.

In addition to importance of this project from the environmental aspect, there is a specific characteristic that makes this project special from others. This characteristic is full implementation of European standards (ENs) in construction, since ENs are still in the process of taking place versus old standards and norms in Bosnia and Herzegovina. These

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ENs also include quality assessment of concrete during its design, production, delivery to the construction site, installation in different construction elements and maintenance. Since this project is of larger importance, a lot of effort was put in concrete quality control, since WWTP consists at most from concrete structures.
This paper brings experiences in construction of buildings from concrete of special characteristics with emphasis on concrete water impermeability as one of principal requests that this type of concrete should fulfil.

2. TESTING OF HARDENED CONCRETE – DEPTH OF PENETRATION OF WATER UNDER PRESSURE ACCORDING TO EN 12390-8:2010

Testing of depth of penetration of water under pressure is performed according to EN 12390-8:2010, which requires following procedures:

- The principle is that water is applied under pressure to the surface of hardened concrete. The specimen is then split and the depth of penetration of the waterfront is measured;
- The test specimen, of given dimensions, shall be placed in any suitable equipment in such a manner that the water pressure can act on the test area and the pressure applied can be continuously indicated;
- The specimen in this particular case is cubic, with dimension of the surface 150/150 mm;
- The test shall be started when the specimen is at least 28 days old. The water pressure should not be applied to a trowelled surface of a specimen. The specimen is placed in the apparatus and applied a water pressure of 500 ± 50 kPa for 72 ± 2 h. During the test, periodically observing the appearance of the surfaces of the test specimen not exposed to the water pressure to note the presence of water. If leakage is observed then consideration of the validity of the result and record is necessary.

Figure 1. Device for water penetration test

- After the pressure has been applied, the specimen should be split in half, perpendicularly to the face on which the water pressure was applied. When splitting the specimen, and during the examination, the face of specimen exposed to the water pressure should be placed on the bottom. As soon as the split face has dried to such an extent that the water penetration front can be clearly seen, the water front on the specimen can be marked;
- Measuring the maximum depth of penetration, expressed in mm, is the test result [1].

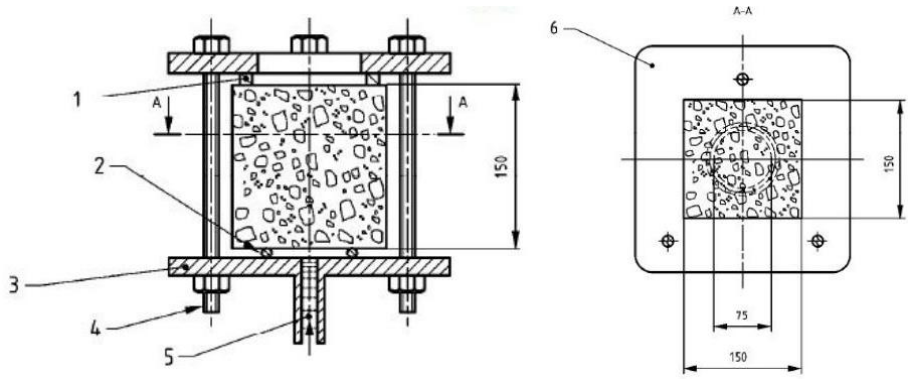

Figure 2. Example of test arrangement [1]

1 – packing piece
2 – sealing ring
3 – screwed on plate
4 – screw-threaded rod
5 – water under pressure
6 – screwed on plate.

3. CONCRETE MIX DESIGN FOR WWTP

Concrete structures were constructed according to two types of concrete mix designs:

- Concrete mix design for reinforced concrete piles; and
- Concrete mix design for all other concrete structure elements of all WWTP facilities.

Main reason for design of two concrete mixes was that concrete of piles needed to be of very high consistency with only two graded aggregate, compared to the concrete of all other structural elements. This was necessary due to simple installation of reinforcement into highly plastic mixture of concrete. The concrete mix for all other facilities is designed with three graded aggregate, since there was no need for highly plastic concrete mix.

Table 1. Concrete mix designs according to declared exposure classes [3]

Label of mixture	Concrete strength class	Exposure class
CBBI 10 PC	C 8/10	X0
CBBI 20 PC	C 16/20	X0
CBBI 25 PC	C 20/25	XC1
CBBI 30 PC	C 25/30	XC2
CBBI 37 PC XF	C 30/37	XC4, XA1, XF3
CBBI 37 SR XF	C 30/37	XC4, XA2, XF3

During the design phase of concrete mix for purpose of construction of WWTP, limit values of content and concrete characteristics were taken into consideration, for defined exposure classes (EN 206/Annex F), so the concrete that is used for plant construction is declared as designed concrete in accordance with point 6.2 EN 206 [3].

Table 2. Mixture materials for 1000 l of fresh concrete [2] [3]

Component material		Base slab and walls of Activated Sludge Tank	Piles of Activated Sludge Tank
		C 30/37, XC4, XA2, XF3, S4, 16mm	C 30/37, XC4, XA2, XF3, S4, 16mm
CEMENT	CEM III/B 32,5 N SR-LH, Cemex	400 kg	410 kg
AGGREGATE			
0 – 4 mm	minced sand	907 kg	1026 kg
4 – 8 mm	crushed stone	181 kg	-
8 – 16 mm	crushed stone	726 kg	809 kg
WATER	local water supply	175 l	183 l
ADMIXTURE 1	superplasticizer Readyplast VP 342, Cemex	2,70kg	3,075 kg
ADMIXTURE 2	air entraining admixture Readyair L300, Cemex	0,20kg	-

Concrete mixes labelled with PC are designed with regular Portland cement and they are used for construction of structural elements in chemically less aggressive environmental conditions and for external elements exposed to freezing, while concrete mix labelled with SR is concrete mix with sulphate resistant cement and could be used for construction of structural elements in chemically moderate and highly aggressive environmental conditions and for external elements exposed to freezing.

Exposure classes for concrete XC and XA are ensured with minimum cement amount, maximum water-cement ratio and minimum concrete strength class, all according to EN 206/Annex F/Table F.1 [3]. In addition, concrete mix design for concrete strength class C 30/37, with ingredients' amount is shown in *Table 2*.

4. TEST RESULTS ANALYSIS OF DEPTH OF WATER PENETRATION UNDER PRESSURE

In this paper, analysis on depth penetration of water under pressure for Activated Sludge Tank is presented. The Activated Sludge Tank is a facility where biochemical purification of waste water takes place. It consists of three chambers, each divided into two sections, so that left and right side of the tank can work independently during maintenance.

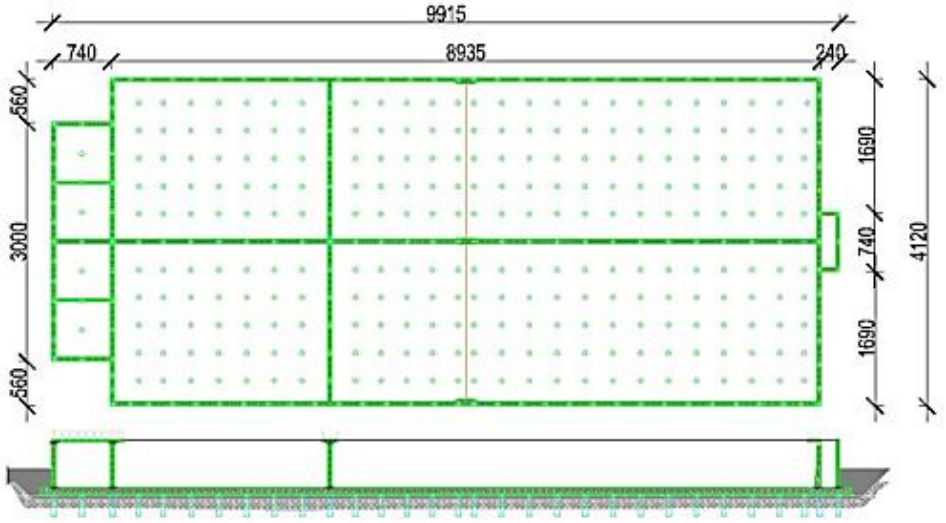

Figure 3. Activated Sludge Tank – disposition [3]

The interesting fact, when observing aspect of concrete works, is that concrete must be water tight in order to prevent mixing of water between adjacent chambers. The reason for this lies in the fact that different processes of purification occur in these chambers, so there must not be any mixing of water due to pollution of purified water. That is why, all concrete structures are designed with 5 cm of concrete cover.
If exclude quantity of concrete placed in piles, the concrete quantity placed in walls and slabs of Activated Sludge Tank is approximately 5000 m^3. The test result analysis of depth of water penetration under pressure is presented in following charts.

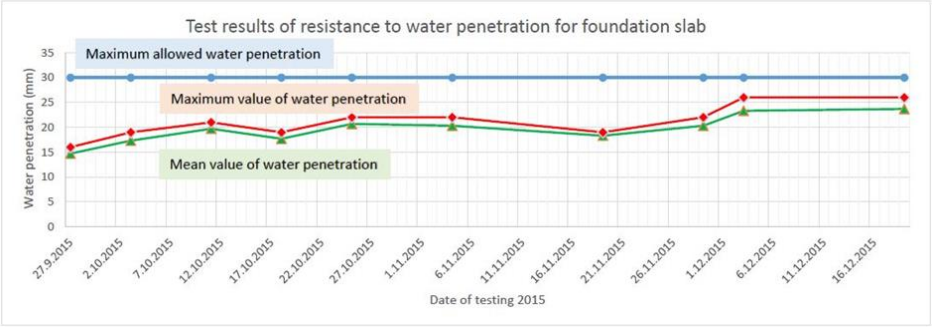

Figure 4. Test results of resistance to water penetration for RC foundation slab

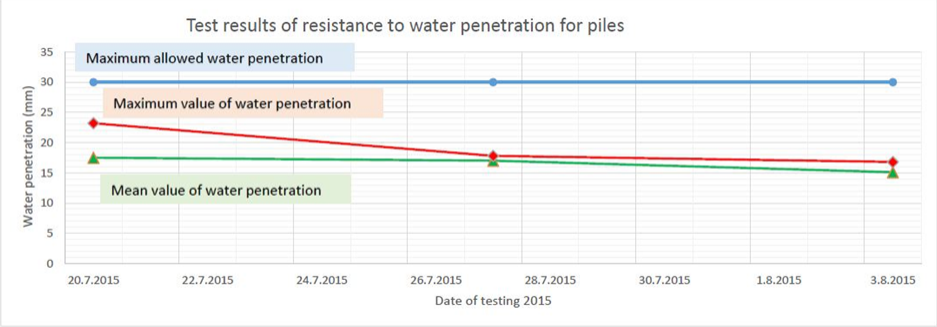

Figure 5. Test results of resistance to water penetration for RC walls

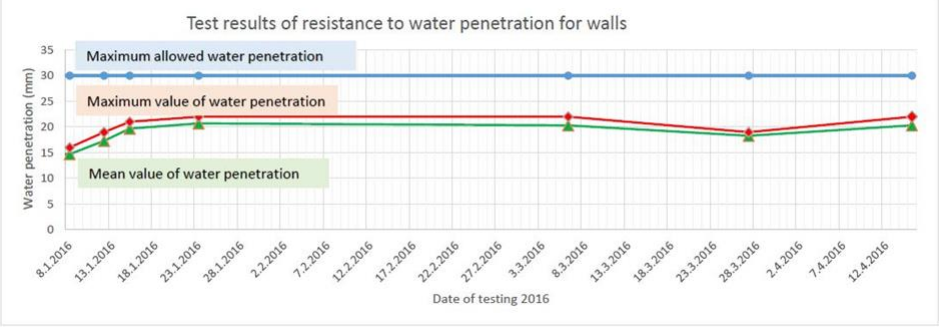

Figure 6. Test results of resistance to water penetration for piles

5. ADDITIONAL TESTS

Although concrete structural elements of Activated Sludge Tank were tested to water penetration resistance, the whole structure was also tested for water tightness with 20 000 m^3 of water.

Figure 7. One chamber of Activated Sludge Tank filled with water for water tightness test

This testing consisted of two phases:

- Saturation phase: phase of saturation of walls and slab with water for 7 days; and
- Testing phase: phase of testing by measurement of water level in the tank on daily basis for 5 days, where water loss (level) should meet limit criteria of permissible water loss after these 5 days.

This test showed that some water leakage occurred through walls, most probably as a consequence of inadequate vibration of walls during casting of concrete in spite of full concrete quality control. However, water loss was below than maximally permissible value for such test.

6. CONCLUSION

Based on stated in text earlier, the following conclusions can be drawn:

- During the design phase of concrete structures of Waste Water Treatment Plant, parameters concerning concrete tightness were taken early into consideration, so that all concrete covers were 5 cm thick, what was satisfactory for water tightness of concrete elements considered;

- Resistance of concrete to water penetration is primarily achieved by application of special sulphate resistant cement with low hydration heat;
- In addition to sulphate resistant cement, superplasticizer admixture also contributes to the resistance to the water penetration to the concrete mixture;
- When using admixtures to concrete mixture, the water-cement ratio should not be above 0,50, to avoid formation of micro porosity and ensure good resistance and duration of concrete structure;
- All maximum depths of water penetration obtained through tests are below the maximum permissible value to which water can penetrate into the concrete;
- Maximum water penetration value was 26 mm on samples taken during casting of walls and foundation slab for Activated Sludge Tank.

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ИСКУСТВА У ИСПИТИВАЊУ ВОДООТПОРНОСТИ БЕТОНА ПРИЛИКОМ ИЗГРАДЊЕ ППОВ У БИХАЋУ

Резиме: *Водонепропусност се дефинише као отпорност бетонске конструкције на продирање воде под одређеним притиском. С обзиром да су хидротехнички објекти углавном израђени од армираног бетона, са намјеном задржавања воде, ови објекти морају бити водонепропусни, па се из тог разлога посебна пажња посвећује пројектовању бетонске мјешавине, укључујући и додатке бетону. Стога, задовољавање овог критерија је било незаобилазно у пројектовању и изградњи Постројења за пречишћавање отпадних вода у Бихаћу, као дио ширег пројекта за прикупљање и третман отпадних вода. Током изградње овог објекта, испитивање водонепропусности је проведено у складу са EN 12390-8:2010. Циљ овог рада је да се презентирају искуства ове врсте испитивања бетона у складу са европским стандардима кроз методологију, те обраду података и резултате.*

Кључне речи: *Водонепропусни бетон, Испитивање, Контрола квалитета бетона, Постројење за пречишћавање отпадних вода у Бихаћу*