Ing. Miroslav Brodňan, PhD.[1)*)]
Ing. František Bahleda, PhD.[1)]
Assoc. Prof. Ing. Peter Koteš, PhD[1)]
dr inż.Wojciech Kubissa[2)]
Ing. Miroslav Strieška[1)]

Diagnostic and repair of sewage treatment plant tanks in Žilina

Diagnostyka i naprawa zbiorników oczyszczalni ścieków w Žilinie

DOI: 10.15199/33.2017.07.18

(Studium przypadku)

Abstract. The paper presents the results of diagnostic measurements realized in the reinforced concrete tanks of sewage treatment plant in Žilina. Diagnostic measurements preceded the subsequently realized reconstruction. The purpose of diagnostic was to determine the carbonation of concrete, concrete covers, diameters and type of reinforcements and corrosion of reinforcement. In some samples of concrete, there were made the chemical analysis and determined the concentration of chloride ions Cl^- and concrete composition.
Keywords: diagnostic of tanks, chemical analysis, rehabilitation, reinforced concrete, sewage treatment plant.

Streszczenie. W artykule przedstawiono wyniki pomiarów diagnostycznych przeprowadzonych w żelbetowych zbiornikach oczyszczalni ścieków w Žilinie. Pomiary diagnostyczne poprzedziły późniejszą naprawę. Celem diagnostyki było określenie głębokości karbonatyzacji betonu, grubości otuliny, średnicy i rodzaju zbrojenia oraz jego korozji. W przypadku niektórych próbek betonu przeprowadzono również analizę chemiczną, oznaczenia stężenia jonów chlorkowych Cl^- oraz składu betonu.
Słowa kluczowe: diagnostyka zbiorników, analiza chemiczna, odbudowa, żelbet, oczyszczalnia ścieków.

The diagnostic measurements realized in reinforced concrete tanks of sewage treatments plant in Žilina (Photo 1) in village Horný Hričov (SČOV Žilina – Intensification) were realized on the basis of order of the company CONTROL-VHS-SK, Ltd., Žilina. The diagnostic measurements were realized in SO 100-09 Activation tank, SO 100-05 Settling tank, SO 100-04 Sand trap, SO 100-11 Sedimentation tank and SO 100-18 Connecting pipes and drains.

The diagnostic measurements were needed for reconstruction planning and intensification of individual building objects and operational files of mechanical and biological degree. The bases for design of individual functional parts are very strict parameters for capacity of sewage treatment plant. The main attention is devoted to the elimination of nitrogen and phosphorus according to requirements of European and Slovak legislation forfilling limits of parameters for capacity of sewage. Then the reconstruction will lead to more effective removal of organic pollution and increase the capacity of the sewage treatment plant from 145 000 (present value) to 191 000 so-called equivalent inhabitants.

Photo. 1. Sewage treatment plant in Žilina
Fot. 1. Oczyszczalnia ścieków w Žilinie

Diagnostic of reinforced concrete tanks

The aim of diagnosis, which was realized by Department of Structures and Bridges (Faculty of Civil Engineering in the University of Žilina) in cooperation with Testing laboratory (Faculty of Civil Engineering in the University of Žilina), was to determinate of the depth of carbonation of concrete in the construction and also it was measured in the laboratory on the drilled core samples (Photo 2, 3). Another measured parameters, were diameters and type of reinforcements, corrosion of reinforcement, concrete cover and location of reinforcement (Photo 4, 5).

The overall construction and technical state of the tanks were also analyzedand in the places, where the corrosion reinforcement was located [1, 3, 9], was controlled the width and development of concrete cracks [4]. The chemical properties of chosen concrete samples (SO 100-09 Activation tank) were investigated in company of Považska cement works, Inc., in town Ladce (Table).

The concentration of individual dioxides was determined by [5] and material properties of concrete was determined by [2]. The chloride ions Cl^- concentration was also determined. The company CONTROL-VHS-SK, Ltd.,

[1)] University of Žilina, Faculty of Civil Engineering, Department of Structures and Bridges
[2)] Warsaw University of Technology, Faculty of Civil Engineering, Mechanics and Petrochemistry
[*)] Corresponding address: brodnan@fstav.uniza.sk

Photo 2. Measurement of carbonation depth of concrete on the construction
Fot. 2. Pomiar głębokości karbonatyzacji betonu w konstrukcji

Photo 3. Measurement in the laboratory on the drilled core samples
Fot. 3. Pomiar w laboratorium na odwiertach rdzeniowych

Photo 4. Corrosion of reinforcement
Fot. 4. Korozja zbrojenia

Photo 5. Detail of reinforcement corrosion
Fot. 5. Szczegóły korozji zbrojenia

Results of chemical analysis of concrete in SO 100-09 Activation tank
Wyniki analizy chemicznej betonu w zbiorniku aktywacyjnym SO 100-09

Component [%]	Sample 1.3 + 5.1 (under the working surface of the water)		Sample 7.1 + 7.2 (above the working surface of the water)		Sample 10.1 + 12.2 (the bottom of the tanks)	
	concrete [%]	soluble ratio [%]	concrete [%]	soluble ratio [%]	concrete [%]	soluble ratio [%]
Insoluble ratio	61.68	–	67.68	–	61.25	–
Loss of ignition	7.01	–	0.39	–	7.65	–
Soluble ratio of SiO_2	12.73	41.10	10.08	50.60	15.42	50.30
Fe_2O_3	1.82	5.88	2.61	5.79	1.35	4.40
Al_2O_3	3.61	11.66	6.05	4.08	1.42	4.63
CaO	9.91	32.00	10.97	33.80	10.36	33.77
MgO	2.62	8.46	1.52	4.85	1.86	6.06
SO_3	0.28	0.90	0.28	0.91	0.27	0.88
Soluble ratio (without loss of ignition)	30.97	–	31.51	–	3068	-
Sum	99.66	–	99.58	–	99.58	–
pH water's lixivium	10.00	–	10.50	–	100	–

Žilina investigated the material properties like compressive strength by the destructive and non-destructive methods, pull out test on the external walls and on the bottom of the tanks, frost resistance of concrete, maximum resistance of concrete to water ingress and water absorption of the concrete.

Results of diagnostic and chemical analysis

Determination of the depth of carbonation of concrete was made on the external walls and on the bottom of the tanks in the places of drilled cores. Before assessment the depth of carbonation in each hole after drilled core, a part concrete was lopped (in the direction to the inside of the hole) in order to obtain of concretein the fresh fracture area. Carbonation of concrete was determined by a simple indicating method, by moistening of concrete with phenolphthalein (0.1% solution in ethanol) [6]. The results of the measurements indicate that the depth of carbonation, at all the tested locations ofthe reinforced concrete structures, do not reach main and distribution reinforcement. It means that until now there is no risk of the corrosion of reinforcement, which is caused by carbonation of concrete.

The concrete cover and corrosion of reinforcement was determined in those places on the walls and on the bottom of reinforced concrete tanks, where the reinforcement is exposed after drilled cores. In these places were not found the reinforcement corrosion. In same places, only surface corrosion was detected, which was caused by the effects of atmospheric moisture by drilled cores. Reinforcement corrosion loss was detected on the place where the concrete cover was dropped out. The reinforcement surface corrosion of distribution reinforcement (type of bar is smooth rough bar of 12 mm diameter) was found on the longitudinal reinforcement and inside walls of the tank (SO 100-09 Activation tank, Photo 6)

Photo. 6. SO 100-09 Activation tank
Fot. 6. Zbiornik aktywacyjny SO 100-09

on the places where the concrete cover was dropped out. The maximum value of corrosion decrease was 0.5 mm. The reinforcement corrosion of main reinforcement (steel grades B 420B of 14 mm diameter) was found above the working surface of the water on the walls of SO 100-05 Settling tank on the places where the concrete cover was dropped out. The maximum value of corrosion decrease was 3.0 mm. In other places and other building objects the concrete cover was not dropped out.

The concentration of chloride ions Cl^- was determined in the reinforcement concrete taken from SO 100-09 Activation and SO 100-05 Settling tank. In all samples were the concentration of chloride ions Cl^-/m_c below the critical value of chloride ions for reinforced concrete construction (C_{krit} = 0.4 Cl^-/m_c) according to STN EN 206 [8]. Concentration of chloride ions Cl^- was converted to the assumed amount of using cement during the production (Cl^-/m_c).

Insoluble ratio in Table represents total volume of aggregate as filler in the concrete. Individual values in the undeteriorated Portland cement are as follows: value of soluble silicon dioxide SiO_2 is 20%, value of iron (III) oxide (Ferric oxide) Fe_2O_3 and aluminium oxide Al_2O_3 are 12.5% and value of calcium oxide CaO, which is the main ingredient of Portland cement is 62.5%. According to STN EN 196-2 [7] the admissible values of magnesium oxide MgO and sulfur trioxide SO_3 in the undeteriorated Portland cement is 2.5%.

The results of chemical analysis show that the Portland cement was used in the concrete production. Lower concentration of CaO documents his wash out from concrete and increased content of SiO_2 corresponds his sufficient amount in the calculation. In the case of samples taken from Activation tank (under the working surface of the water) and from the bottom of the tank, a higher amount of MgO was found, which documents the starts of corrosion of magnesium. The high loss on ignition (more than 3%) represented that the chemical ingredients was used in the production of the concrete.

Design of rehabilitation tanks by the results of diagnostic

On the base of diagnostic results, there were recommended rehabilitation arrangements, which subsequently were realized. The whole circumferential walls of the SO 100-09 Activation tank was needed to strengthen with a new reinforced concrete layer and on the bottom of the tanks was applied a suitable materials for rehabilitation (Photo 7).

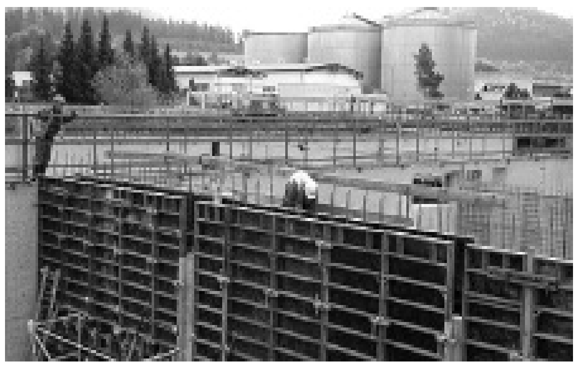

Photo 7. Rehabilitation of SO 100-09 Activation tank
Fot. 7. Odbudowa zbiornika aktywacyjnego SO 100-09

The circumferential walls of the SO 100-05 Settling tank was recommended only to paint by protective waterproofing coating, the bottom and the crown of the tanks was applied a suitable materials for rehabilitation. In another diagnostic construction including SO 100-04 Sand trap were applied suitable materials for rehabilitation.

Conclusions

The paper describes the process, methods and the results of diagnostics realized on the tanks of sewage treatment plant in Žilina (SO 100-09 Activation tank, SO 100-05 Settling tank, SO 100-04 Sand trap, SO 100-11 Sedimentation tank and SO 100-18 Connecting pipes and drains). The results of the diagnostic measurement were used for design of rehabilitation of the tanks, which were subsequently realized by the implementation company.

Total final value of contract the reconstruction of sewage treatment plant in Žilina in village Horný Hričov realized for the company North Slovakia Water and Sewage, Inc., was 15.318 millions EUR carried out the company VÁHOSTAV-SK, Inc. Žilina.

References

[1] Brodňan Miroslav, Marián Drusa, Jozef Vlček, František Bahleda, Michal Grinč. 2016. „Effect of chemical corrosion and aggressiveness of ground water on operational lifetime of concrete structure of deep pit. XXII." International conference „CONSTRUMAT 2016 – Conference on Structural Materials", Stará Živohošť, Czech Republic, p. 295-304 (in Slovak).

[2] Jambor Jaromír. 1953. *Chemical analysis of the construction industry.* Publisher: SAV Bratislava 584 p. (in Slovak).

[3] Jaśniok Tomasz, Mariusz Jaśniok, Adam Zybura. 2013. „Studies on corrosion rate of reinforcement in reinforced concrete water tanks". *Ochrona przed Korozją*, Vol. 56, 5: 227 – 234.

[4] Koteš Peter, Ján Kozák. 2014. Reinforcement Corrosion versus Crack Width. Advanced Materials Research, Vol. 897, Binders and Materials XI, Trans Tech Publications Switzerland, p. 161-164. DOI 10.4028/www. scientific. net/AMR. 897.161.

[5] STN 72 0100. 1983. (+ change „a", 1986) Basic analysis of silicates. Common regulations. ÚNMS Bratislava.

[6] STN EN 14630. 2007. Products and systems for the protection and repair of concrete structures – Test methods – Determination of carbonation depth in hardened concrete by the phenolphthalein method. ÚNMS Bratislava.

[7] STN EN 196-2. 2013. Methods of testing cement. Part 2: Chemical analysis of cement. ÚNMS Bratislava.

[8] STN EN 206. 2015. Concrete. Specification, performance, production and conformity.ÚNMS Bratislava.

[9] Vaněrek Jan, Rostislav Drochytka. 2002. Detection of corrosion rate of steel in reinforced concrete. In: 3rd International Conference Concrete and Concrete Structures, 1st ed. Žilina, Faculty of Civil Engineering, p. 137 – 142.

Acknowledgement

The research is supported by the Slovak Research and Development Agency under contract No. APVV-14-0772 and by Research Project No. 1/0566/15, 012ŽU-4/2016 of Slovak Grant Agency and also by the project SK-PL-2015-0004 and DS-2016-0039 in frame of bilateral cooperation.

Przyjęto do druku: 22.05.2017 r.