Experimental Verification of the Material Properties of Concrete 50 Years Old Wastewater Treatment Plant

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Abstract: The article focuses on the investigation of the environmental impact of contaminated by colloidal aggressive substances on a 50-year-old wastewater treatment plant, where the sampling of core boreholes of DN150mm × 370 mm in the tank was made. The properties investigated were the microstructure and compressive strength of the concrete. The results showed that the aggressive environment had no effect on the resulting compressive strength of the concrete.

Keywords: Degradation of concrete; Corrosion; Aggressive environment

1 Introduction

The aggressive environment in wastewater treatment plants is a constant problem due to the observance of hygiene standards in the elimination of the spread of bacteria, fungi, and viruses. So that the ecosystem is not damaged. The influence of wastewater has an impact on the construction part in the treatment stations, and subsequently it cannot be done without local remediation. Nowadays, the design of monolithic constructions mainly uses the watertight concrete system (WCS), "white tub system", for its waterproof properties with the extension of the curing time to reduce microcracks in concrete constructions [1]. Wastewater treatment plants cannot do without monolithic constructions with regard to their resistance to other materials. Their maintenance is appropriate due to the influence of attacking the aggressive environment with polluted water due to the chemical composition and degradation processes. The resulting value for pre-purified water is monitored and projected to the values of BOD (Biochemical Oxygen Demand), COD (Chemical Oxygen Demand), US (Undissolved Substances), N-NH4 (Ammonia Nitrogen), P_{total} (Total Phosphorus), N_{total} (Total Nitrogen) [2]. The main component of pollution are substances from human activity (humanoid substances), micropollutant substances and unwanted substances. These attributes are reduced with the help of mechanization, separated (mechanical cleaning) and further stabilized by a biological cleaning process [3]. Using the microorganism in which they live, they grow and reproduce. As a result of this biomass, CO_2, and hydrogen sulphide H_2S are released, which supports the degradation of concrete structures due to CO_2. The effect of poor maintenance of wastewater treatment plant managers with insufficient oxygenation is the conversion of H_2S to H_2SO_4, which reduces the alkalinity of hardened concrete supported by steel corrosion. The treatment process is supported by stabilization using nitrification to nitrates with the help of a phosphorus precipitation stabilizer [4]. This has the effect of promoting penetration into the pore structure of concrete, where crystallization and volume increase occur. With low strength, microcracks may occur on the surface of the concrete. In an environment in which concrete structures are stressed, the penetration of undesirable substances occurs and consequently the degradation of concrete structures, in extreme cases, chemical corrosion of steel occurs when there is insufficient coverage [5]. Another factor of corrosion due to carbonation supported by carbon dioxide. Chemical action and

microstructural aggressive environment caused by organic acids reducing the alkalinity of concrete and soluble salts reducing the durability of concrete [6].

The research dealt with the influence of an aggressive environment on monolithic structures at a specific treatment plant, where reconstruction was taking place to increase the capacity of the wastewater treatment plant with the modernization of the technological part. The samples were taken from the place of constant influence of an aggressive environment, in which the cleaning cycle (aerobic and anaerobic) took place, according to the needs of the user. The selected site was chosen for its age and the effects of several factors without precipitation of phosphorus.

2 Material and samples

The wastewater treatment plant is in the village of Horní Bezděkov, where intensification and capacity increases were carried out. As part of the demolition work, the existing tank was used, and its volume was increased. (Fig. 1). The tank was used for 50 years, for the sludge separation process and for the areobic process (chemical cleaning), as needed by the plant manager. The individual boreholes were chosen in heights of tank, according to the frequencies of environmental contamination. In total, there were 7 bores. Of this, Core_4, broke off during the drill and was replaced at the same height of tank by Core_4x. Optical microscopy was carried out on the lowest outcrop Core_1, it was the most contamination site of the permanently flooded. The location of the individual core drillings can be seen in (Fig.1). Also, in the Fig. 1 you can see the maximum and minimum level of contaminated water during operation. The height is given from the sea level of the Baltic system.

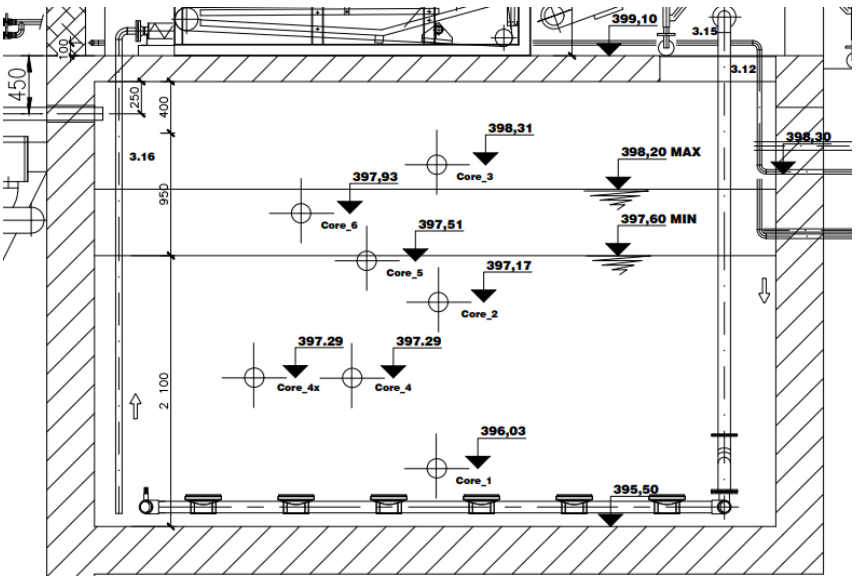

Fig. 1 Cut through the sampling point in the tank, scale 1:50.

Core drilling was carried out with the help of a DN150 mm diameter diamond core coring machine with cooling and pumping of drink water. The resulting individual dimensions of core were approximately 144.60 mm and 370 mm in height for a total of 7 pieces.

3 Experimental methods

Optical microscopy was used to describe to the microstructure of the concrete by ZEISS Axio Zoom V16 Stereo Zoom Microscope. The microscopic images were taken on core of borehole 1 (Core_1). The area examined was on a longitudinal section of the sample Core_1. The examined area had an area of 540,20 cm^2 at a magnification of 3.5 ×. For this reason, a 9 × 9 image matrix was used. The compressive strength was determined by uniaxial compressive test on the individual core of borehole. The specimens were moulded so that their height was fixed at the same value of 300 mm in order to comply with the condition of twice the diameter according to EN 12390-3 [7]. The testing was displacement controlled at a constant rate of 5 mm/min.

4 Results and discussions

In Fig. 2 we can see the microstructure of the Core_1 sample detected by optical microscopy. The sample (Core_1) shows the effect of the aggressive environment on the concrete structure. Part A in Fig. 2 shows the microstructure towards the soil showing a covering layer of cement paste of approximately 950micron thickness and this layer in Fig. 2 Part B cannot be seen due to environmental degradation contaminated by colloidal substances. The structure remains undisturbed in the longitudinal section direction.

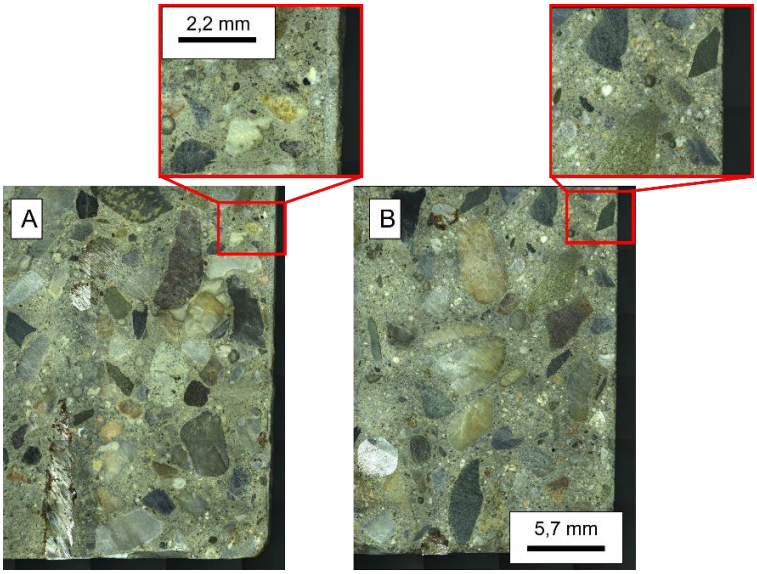

Fig. 2 Image for optical microscopy magnification 3.5x.

Table 1 shows the results of mechanical destructive testing of the individual samples, the range of compressive strength values was from 35.85 to 43.32 MPa. The Core_4x sample was removed from the statistics due to non-standard testing. The average strength of the concrete was at 37.49 ± 5.03 MPa. Considering the standard deviation, it can be specified that all the speciement had the same compressive strength values. The result shows that the aggressive environment has an effect on the cover layers and does not affect the final strength of the concrete.

Table 1. Compressive strengths of samples analysed.

Set	Diameter [mm]	Area [mm^2]	Height [mm]	Weight [g]	Load [kN]	Compresive strenght [MPa]
Core_1	-	-	-	-	-	-
Core _2	144.73	16451.55	297.00	2335.80	670	40.73
Core _3	144.27	16347.15	297.00	2249.38	612	37.44
Core _4	144.66	16435.64	296.00	2364.46	712	43.32
Core _5	144.62	16426.55	297.50	2301.05	495	30.13
Core _6	144.64	16431.10	296.50	2277.59	589	35.85
Core _4x	144.19	16329.02	185.50	2273.00	427	26.15

Conclusion

Concrete samples (core boreholes) taken from the overburden were examined as part of the research. Over a period of 50 years of exposure to an aggressive environment The results showed the properties of concrete and their compressive strength at 37.49 $\pm$ 5.03 MPa, this is the strength in the entire profile with regard to the selection of a sample from one-way places of different exposure to an aggressive environment. Optical microscopy showed the occurrence of attack to the upper depth of the concrete.

Future research will address comparison of new samples supported by phosphorus precipitation and the effect of microorganism in monolithic constructions. Growth, propagation and settling in a porous structure.

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References

[1] Radziejowska A. and Linczowski K., "Selection of "white tub" technology using milti-criteria analysis – a case study," *Czasopisma Polska Academia Nauk*, **68**, pp. 446-449 (2022).

[2] Hassen E. B. and Asmare A. M., "Modeling and monitoring of treated wastewater based on water quality assurance parameters," *International Scientific Organization, Chemistry International*, **5**(1), pp. 87-96 (2019).

[3] Nasr F.A, Doma H.S., Abdel-Halim H.S. and El-Shafai S.A., "Chemical industry wastewater treatment," *Water Pollution Research department*, **30**, pp. 1183-1206 (2004).

[4] Biological Wastewater Treatment – What Is It and How Does It Work? Water Treatment, Wastewater, Air and Energy, "Water Treatment Services", *Available from* https://watertreatmentservices.co.uk/biological-wastewater-treatment-how-does-it-work/ *Accessed:* 2023-04-02

[5] Chakraborty S., Mandal R., Chakraborty S., Guadagnini M. and Pilakoutas K., "Chemical attack and corrosion resistance of concrete prepared with electrolyzed water," *Journal of Materials Research and Technology*, **11**, pp. 1193-1205 (2021).

[6] EN 12390-3 (731302), Testing hardened concrete, *Compressive strength of test bodies – part 3*, (2020) ICS 91.100.30