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Research paper

Concrete degradation in an over 100-year-old drinking water treatment plant, a case of lime leaching from the water retaining tanks

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Abstract: The problem of the concrete durability counted in tens of years is not a frequent subject of research, despite the fact that the oldest structures made with the use of Portland cement are about 140 years old, and the large size engineered constructions (like dams,breakwaters, bridges, chambers, halls) are 110 years old. The considered tank belongs to the last group of objects.In the years 1908–1909, a drinking water treatment station was built for the city of Poznan, which was then 196. 000, taking it from the Warta River. The plan dimensions are 65.5 ×21.5 m, and the height is 9.0 m above and 5.0 underground. It is a pearl of industrial architecture of the end of the 19th and the beginning of the 20th century with the most modern technological equipment in the world at that time. In the underground part, a large-size reinforced concrete tank with a ribbed ceiling supported in the middle with reinforced concrete columns was constructed throughout the projection.Those were the times when the first bold constructions from the cement concrete were built in the world, very few of which have been preserved till the present day. In order to estimate the durability of the concrete, after several decades of influence of very high relative air humidity, it is very significant to check the changes in its microstructure, which influence its strength parameters. This year the author of the project conducted a material and structural analysis of the technical condition of the over hundred ten year old tank structure, which proved that the compressive strength of the concrete is lowered, and there are numerous cracks of the walls and the ceiling, and also some accumulations of white lines and icicles outside. The SEM, EDS and XRD analyses proved that the phase composition of the concrete in the barrier thickness is variable. In the lower layers of the concrete a calcium hydroxide concentration is observed, which outside the barrier changes into the calcium carbonate. The migration of the Portlandite in the direction of the inside of the tank with very high relative air humidity (>95%) results from the mass diffusion caused by different concentration of the porous liquid in the outer and inner layers of the barriers. Those are very slow processes, that last tens of years during the exploitation of the tank. They are beneficial in terms of the gradual alkalinity increase, which protects the steel against corrosion, but they can be harmful due to a local increase of the porosity and the decrease of the concrete strength.This phenomenon has been described in the literature as elution of calcium ions from the concrete structure. Numerous articles in this field focus on creating a sufficiently durable concrete structure by dosing appropriate mineral additives, rather than on several dozen years of observations of the objects in use. Therefore, the intention of the author of this article is not to model the Ca^{2+} leaching process in a laboratory, but to analyze the gradual degradation of an industrial facility subjected to direct action of water over a period of one hundred years.

Keywords: durability, concrete tank, leaching of Ca^{2+}, SEM, EDS, XRD analysis

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1. Introduction

The turn of the XIXth and XXth century was the time when large size concrete structures were built in the world, such as military forts, first motorways constructed in the USA from the cement concrete, or first high buildings, like Ingalls Building in Cincinnati, USA, constructed in 1902–1903 [1].

In 1857 the cement works Grodziec in Poland was built, which was then the 5th cement works in the world and 3rd in Europe. This was an impulse to a development in concrete technology in Poland, which was initially related to making huge elements, such as drinking water tanks or tanks for sewage (famous Imhoff tanks), bridges, river canals, buildings of the Warsaw–Vienna Railway, and also sports arenas (concrete Centennial Hall built in 1911 in Wrocław [2]). Many of these structures function nowadays, which makes the question of concrete durability and lifting capacity of those historic buildings quite relevant.

Literature on durability of 100 year old concretes is not very rich [3, 6, 9], and the research held on the same structure for 100 years – unique. The Newsletter 04 JSCE described the Japan's 100-year-Old Otaru Port Breakwater [19]. Several dozen years' research on concrete compressive strength on control specimens made in the years 1910, 1923 and 1937 were done by Washa W.G., Wendt F., Saemann C.J., Cramer M. St. [4, 5]. During the research the changes of concrete characteristics were measured for 50 years, with reference to the oldest, roughly milled cements with the relatively high content of C_2S and it was stated that the concrete strength increased up to 50 years of exploitation. Cements that were produced later and of finer milling with less C_2S, gained the best strength after 10 to 25 years. Later the strength decreased. It was stated, that with proper water care the concrete shows periodic self-tightening and increased strength [5]. Later, after tens of years, the strength decreases are related to the changes of the internal structure of the concrete, which is presented in the author's research of 80 year old concrete roads [10].

The compressive strength of 80-year-old original concrete pavement decreased during last 15 years from 80 MPa to 74.3 MPa (7.1% loss of strength), comparing tendencies after 25–50 years exploitation outdoor storage concrete samples are described by the authors of paper [5, 6].

In the last years the author of this article conducted a material and structural analysis of the technical condition of the over hundred year old tank structure filled during that time with drinking water, which proved that the compressive strength of the concrete is lowered, and there are numerous cracks of the walls and the ceiling, and also some accumulations of white efflorescences. Similar phenomena have so far been described in the literature in connection with the permanent, long-term impact of water on river dams [7]. Described there three types of lime leaching on water retaining concrete structures, like leaching through very porous concrete, from free concrete surfaces and through cracks in concrete. There are also other durability problems of the dams [8], but they are not the subject of this article.

2. History of drinking water filters in Poznań and its current technical condition

2.1. Architectural description of the building

The building of the water station belongs to a collection of post-industrial facilities located in the very heart of Poznan, near the historic Pallatium of the first Polish Lord, Mieszko I from the 9th century and the first stone cathedral from the 10th century.

The history of the filter building dates back to 1854. In 1908–1909, the first filters to treat drinking water taken - as in other modern cities – directly from the Warta River, were expanded according to the design of the Berlin Joint Stock Company Diss & Co., equipping them with steel vats from the New York-based Jewell-Export-Filter Company.

In 1911, Hans Mertens, director of the Municipal Waterworks, wrote about this reconstruction: *"6 filters were installed. The basement rooms of the building were expanded as a backup clean water tank. The water extracted from the well, in the amount of 5,000 m^3 per day, is colored a dark brown liquid. The water, if left standing long enough, becomes completely clear, has 6 degrees of hardness and a temperature of 12°C. The water lifted by the pumps flows into the city through three pipes with a diameter of 550, 500 and 225 mm under pressure of 6 atmospheres. Consumers receive water directly from the pressure pipes"*.

The general view of the historical building is presented in Fig. 1. The Filter Hall was operated until 1991, and the reservoir under the filters until 1995. Water Supply Station with a daily capacity of approx 40 thousand m^3 water was taken out of service in 1993. The

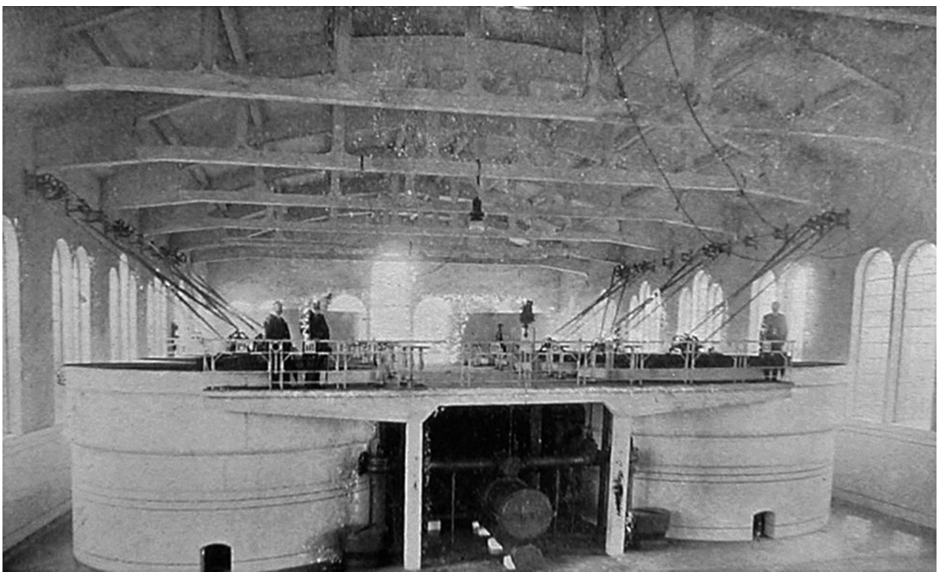


Fig. 1. Water treatment plant – view of the hall from 1910 [20]

base of the building is a reinforced concrete pool of a large water tank with dimensions of 65.5 × 21.5 × 4.5 m, occupying the entire storey of cellars. The reinforced concrete structure of columns and beams above the pool is covered with a solid concrete ceiling supporting the steel filters with a circular projection.

The external walls of the building have a traditional structure made of full red brick, characteristic of industrial and municipal buildings from the turn of the 19th and 20th centuries. In the upper part of the walls, above the windows, a common way of decoration was used at that time, consisting in contrasting brick elements with divisions of the plastered wall surfaces with a lime-cement plaster of white color.

In the base level of the ground floor and at the level of the window sills, stripes of dark green glazed cornices were made. From the inside, the walls, including the concrete bases of the steel filters, are covered with white ceramic tiles decorated with narrow red stripes of the decor. The structure is topped with a semicircular ceramic vault based on transverse reinforced concrete trusses. Similarly, all window openings and decorative linings were topped with semicircular lintels, which in the gable parts were covered with wider arcades, and the plastered surfaces obtained vertical divisions of brick stripes.

Such decorative forms of facade division are inspired to some extent by the architecture of the Northern Renaissance and the Geometric Art Nouveau. They are an artistic development of a simple, functional shape of the solid. The cross section of the historical building is presented in Fig. 2, architectural details in Fig. 3.

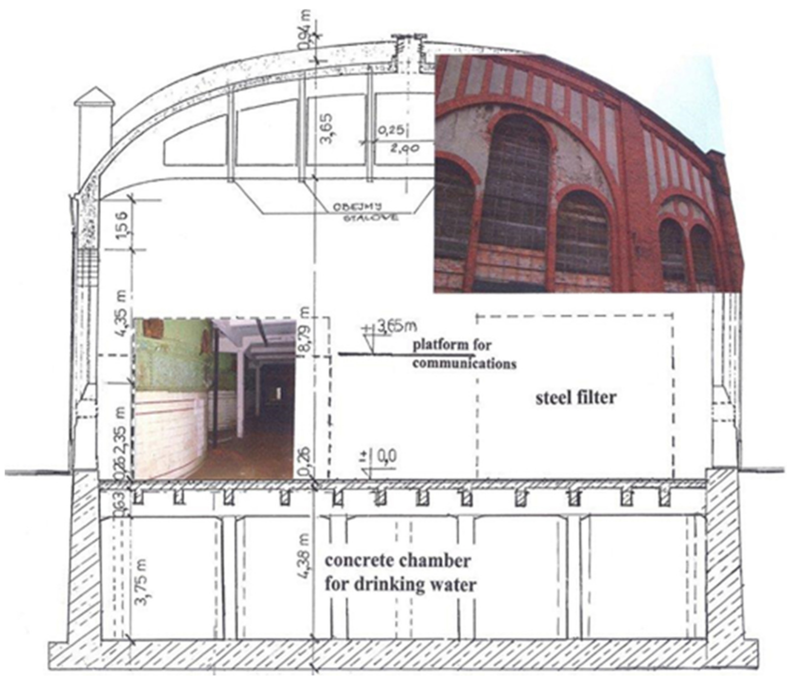


Fig. 2. The cross section of building

Fig. 3. Finishing details of external and internal cornices of ceramic coverings and the bottom of the steel filters showing the filtering grate

2.2. The current technical condition of reinforced concrete structures

Until 2009 the building was used for water filters and storage of drinking water for the city citizens. In 2020 the technical condition of the chamber was checked. The examination discovered many cracks of the concrete peripheral walls, internal reinforced concrete posts and monolithic reinforced concrete ceiling over the water tank. All the cracks were filled with white substance, and in some places on the ceiling there were also white stalactites. The current technical condition of the described structure is shown in Fig. 4 and Fig. 5.

Fig. 4. Reinforced concrete wall of tank from outside and inside with leaks of white efflorescence

Fig. 5. Wall and pillar supporting rib-and-slab floor. Visible cracks filled with white compounds

Tests of compressive strength of concrete on core specimens taken from the structures revealed a very low strength of the concrete at the moment – only 12.0–14.0 MPa, with the density of 2200 kg/m^3 and water absorption by weight of 5.1‰. The concrete in the core specimen taken from the ceiling is very inhomogeneous, porous, with signs of leaching of the cement stone and clearly visible white internal deposits, as well as internal delamination (Fig. 6–9).

This level of concrete strength could be observed in Poznan also in other massive structures built in 1910. Protection from corrosion was ensured by external burning cement plasters. In the analyzed building low concrete strength is the main reason for the loss of load capacity

Fig. 6. Porous bottom part of core specimen ϕ 100 mm

Fig. 7. White drop-stones in the structure of bottom part of core specimen

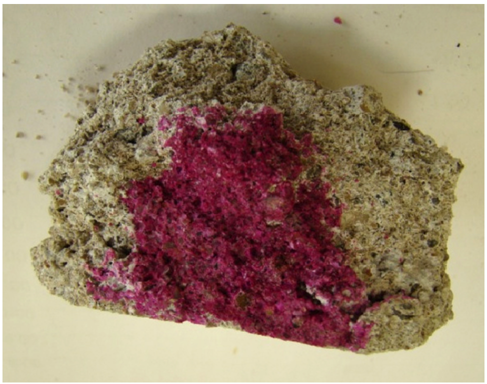


Fig. 8. Carbonation test in the bottom part of core specimen

Fig. 9. Carbonation test in the bottom part of core specimen

of the construction, which results in cracking of its elements. Migration of the white chemical compounds from outside to inside of the water tank (thus from the low relative humidity environment to the space over the water surface with very high relative humidity – over 95%) demands a wider explanation, since those processes have definitely weakened the structure of the concrete.

3. Experimental process and results

The phenomenon of migration of calcium compounds into the inside of the water tank was analyzed with the use of XRD, SEM and EDS method in order to define the phase composition of the concrete and the cement applied, as well as the intensity of occurrence for particular compounds in different parts of the structure.

3.1. XRD analysis of samples taken from the wall and floor

Concrete samples taken from two areas, presented in Fig. 10 as A and B, underwent grinding according to current research procedure and their phase composition was defined. Samples: A – taken from the wall (Fig. 4), B – taken from the upper part of core sample in the upper surface of floor (Fig. 6). In the carbonation test phenolphthalein does not change the color to pink. Sample A is a carbonated concrete, sample B – concrete free of leached basic compounds. In the both cases there are conditions to rapid corrosion of steel reinforcement.

PHILIPS X-ray machine with "Cu" lamp and high voltage generator PW 1140 and vertical goniometer PW 1050/70 were applied. Measurements were taken with the following settings: high voltage generator 35 kV and 20 mA. Goniometer: crack 1° – preparation – crack 0,1 mm – monochromator – proportional counter. Samples underwent XRD measurements within range 5–75 2Θ with constant movement of the goniometer arm of 0.05 2Θ and count time equal 3 seconds. The XRD test results of the separated concretes marked with (A) and (B) are presented in Fig. 11.

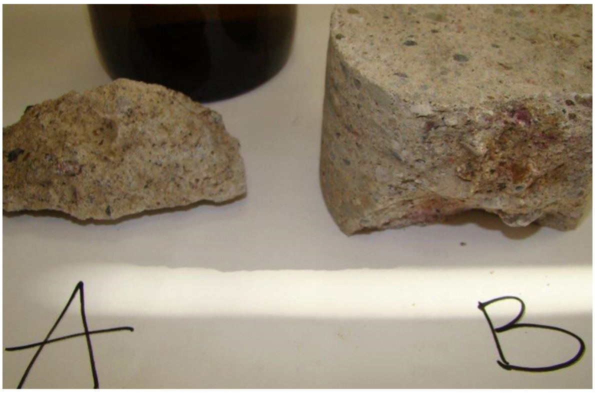


Fig. 10. Samples: A – taken from the wall and B – taken from the upper part of core floor sample

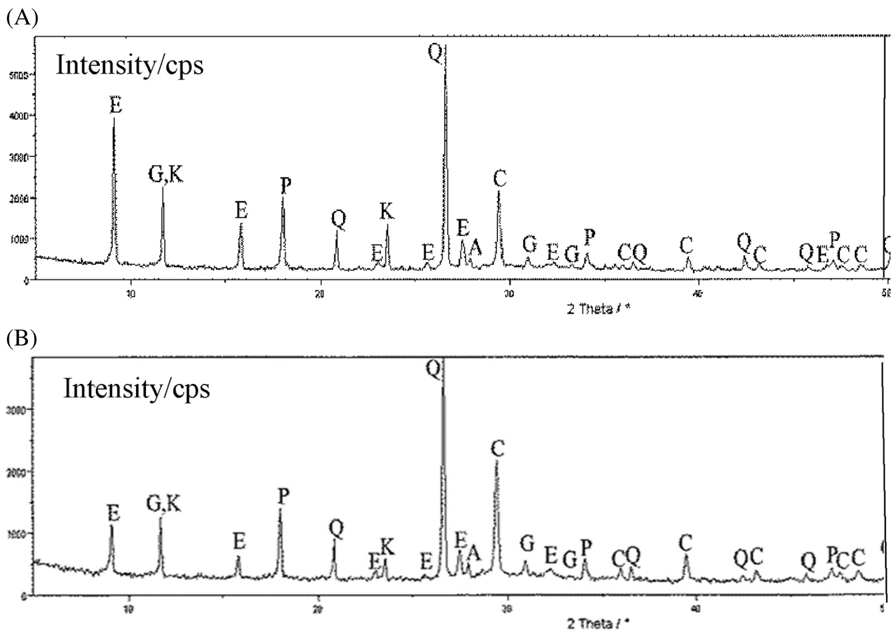


Fig. 11. Phases formations during long time hydration of portland cement concrete. Symbols of concrete phases: A – albite, Q – quarc, C- calcite, E – ettrigite, G- gipsum, K – carboaluminate, P – portlandite

Phase analysis of both concrete samples does not show significant differences. The analysed samples can be divided with regard to occurrence of two types of crystalline phases. Crystalline phases coming from the aggregate in the concrete, such as quartz and albite, as well as phases from cement and coming from its hydration, such as: ettringite, portlandite, carboaluminate, calcite and gypsum.

Taking into consideration the working conditions and the same way of sample preparation the half-quantitative occurrence of particular crystalline phases can be approximately defined. The counting sort analysis and the analysis of crystalline phase peak intensity show a definitely unambiguous tendency. In the (A) sample, in comparison with sample "B", there are much more crystalline phases coming from ettringite and quartz. Much more plaster phase and carboaluminate is visible, but since it is the most intense reflex of both phases in the same angle range 2Θ, it is hard to define clearly which phase prevails. The amount of portlandite and albite phase in both tested samples is similar. The only difference in the analysis is ettringite and calcite. We find more etytringite in sample A, but in sample (B) more calcite.

3.2. SEM and EDS analisys samples taken from the wall and floor

With the use of scanning electron microscope S-3400 N microphotographs and analyses of the occurrence intensity of particular elements in samples A and B were made. The results of the research are presented in Fig. 12 to Fig. 16 and Tables 1 to 6. Each of the figures contains the SEM micrograph and EDS results in the form of a graph and tabular summary of the frequency of occurrence of individual chemical elements.

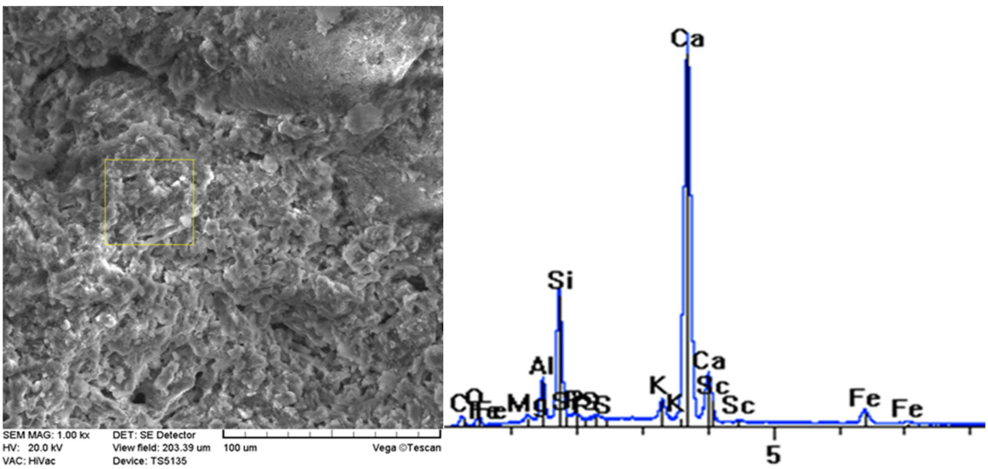


Fig. 12. Analysis of the typical part of outdoor wall (sample A). X-ray photography, the analysis of elements occurence

Table 1. EDS yelloow area

Element	C	O	Mg	Al	Si	S	K	Ca	Sc	Fe	P	Total
Line	KA1	KA1	KA1	KA1	KA1	KA1	KA1	KA1	KA1	KA1	KA1	–
Wt, %	21.1	16.32	0.56	3.40	9.76	0.30	1.41	42.10	0.83	3.50	0.64	100.00
At, %	39.28	22.81	0.51	2.82	7.77	0.21	0.80	23.49	0.41	1.44	0.46	100.00

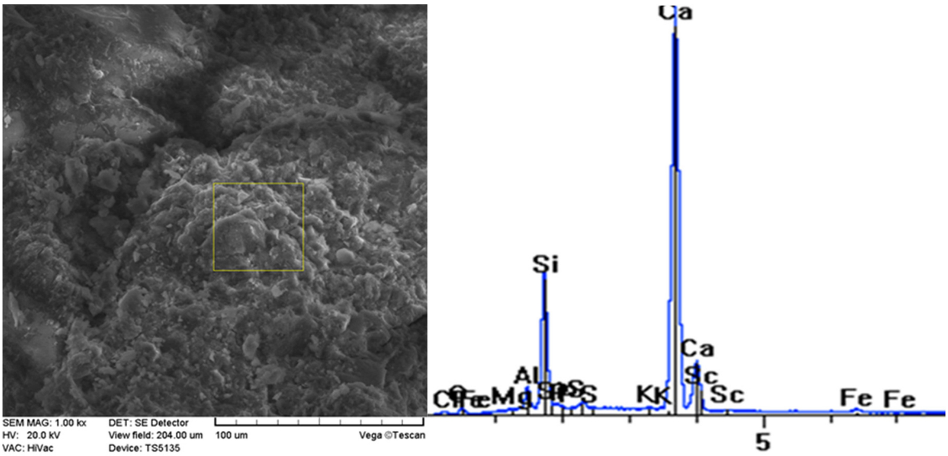


Fig. 13. Analysis of typical part of floor (sample B) – upper part of floor. X-ray photography, the analysis of elements occurence

Table 2. EDS yellow area

Element	C	O	Mg	Al	Si	S	K	Ca	Sc	Fe	P	Total
Line	KA1	KA1	KA1	KA1	KA1	KA1	KA1	KA1	KA1	KA1	KA1	–
Wt, %	6.73	12.38	0.12	2.37	13.93	0.87	0.00	61.16	1.15	0.94	0.35	100.0
At, %	15.87	21.92	0.14	2.49	14.05	0.77	0.00	43.24	0.72	0.48	0.32	100.0

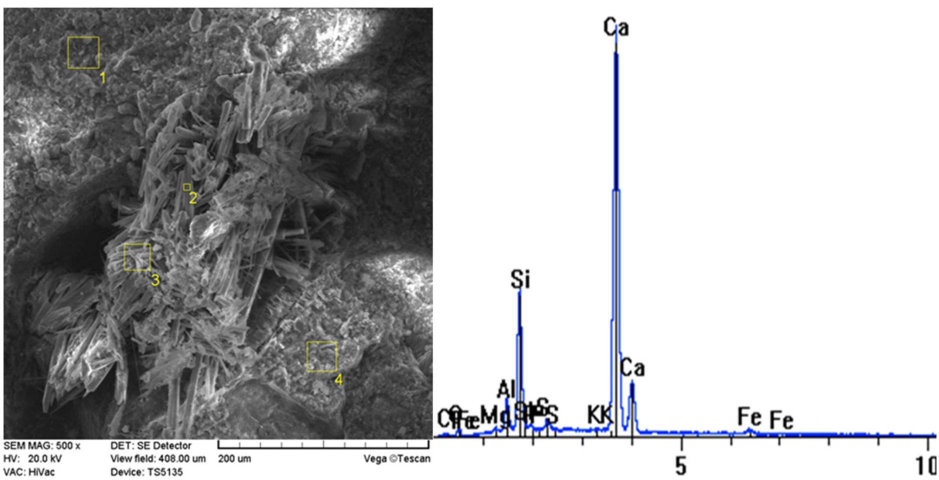


Fig. 14. Analysis of upper part of floor (sample B) riched in ettringite. X-ray photography, the analysis of elements occurence

Table 3. EDS. Area 1, 2, 4

Area 1

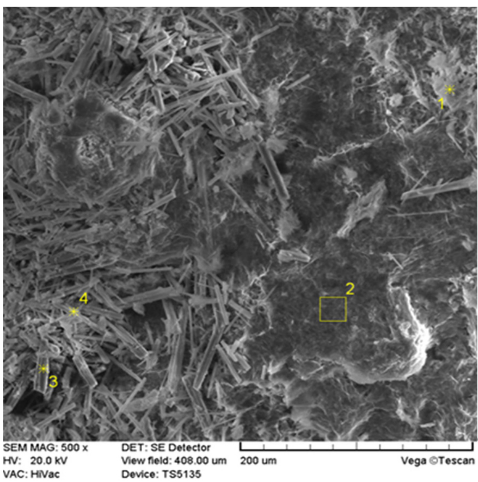
Element	**C**	**O**	**Mg**	**Al**	**Si**	**S**	**K**	**Ca**	**Sc**	**Fe**	**P**	**Total**
Line	KA1	KA1	KA1	KA1	KA1	KA1	KA1	KA1	KA1	KA1	KA1	–
Wt, %	6.73	12.38	0.12	2.37	13.93	0.87	0.00	61.16	1.15	0.94	0.35	100.0
At, %	15.87	21.92	0.14	2.49	14.05	0.77	0.00	43.24	0.72	0.48	0.32	100.0

Area 2

Element	**C**	**O**	**Mg**	**Al**	**Si**	**S**	**K**	**Ca**	**Sc**	**Fe**	**P**	**Total**
Line	KA1	KA1	KA1	KA1	KA1	KA1	KA1	KA1	KA1	KA1	KA1	–
Wt, %	9.45	22.15	0.00	6.05	2.80	13.45	0.00	45.86	0.00	0.00	0.23	100.0
At, %	19.35	34.04	0.00	5.52	2.45	10.32	0.00	28.18	0.00	0.00	0.19	100.0

Area 4

Element	**C**	**O**	**Mg**	**Al**	**Si**	**S**	**K**	**Ca**	**Sc**	**Fe**	**P**	**Total**
Line	KA1	KA1	KA1	KA1	KA1	KA1	KA1	KA1	KA1	KA1	KA1	–
Wt, %	3.44	7.78	0.13	1.55	11.95	0.98	0.00	71.72	0.00	2.21	0.23	100.0
At, %	9.16	15.54	0.18	1.84	13.60	0.98	0.00	57.20	0.00	1.27	0.24	100.0



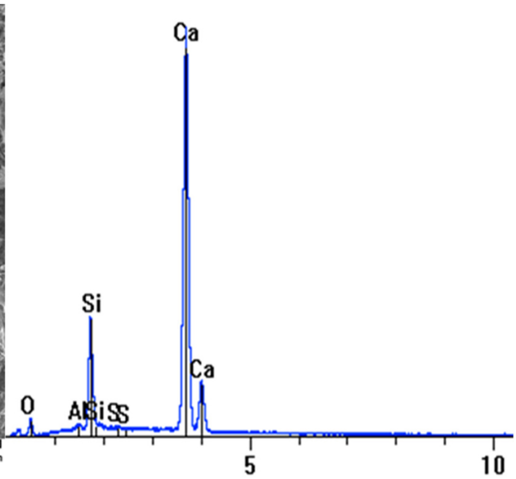


Fig. 15. Analysis of bottom part of floor (sample B) riched in ettringite. X-ray photography, the analysis of elements occurence

Table 4. EDS.Area 1, 2, 4

Area 1

Element	O	Al	Si	S	Ca	Total
Line	KA1	KA1	KA1	KA1	KA1	–
Wt, %	32.31	2.20	9.61	2.58	53.30	100.00
At, %	52.40	2.12	8.88	2.09	34.51	100.00

Area 2

Element	O	Al	Si	S	Ca	Total
Line	KA1	KA1	KA1	KA1	KA1	–
Wt, %	31.33	0.52	10.37	0.11	57.67	100.00
At, %	51.68	0.51	9.74	0.09	37.98	100.00

Area 4

Element	O	Al	Si	S	Ca	Total
Line	KA1	KA1	KA1	KA1	KA1	–
Wt, %	16.60	3.22	0.74	7.90	71.54	100.00
At, %	32.28	3.72	0.82	7.66	55.33	100.00

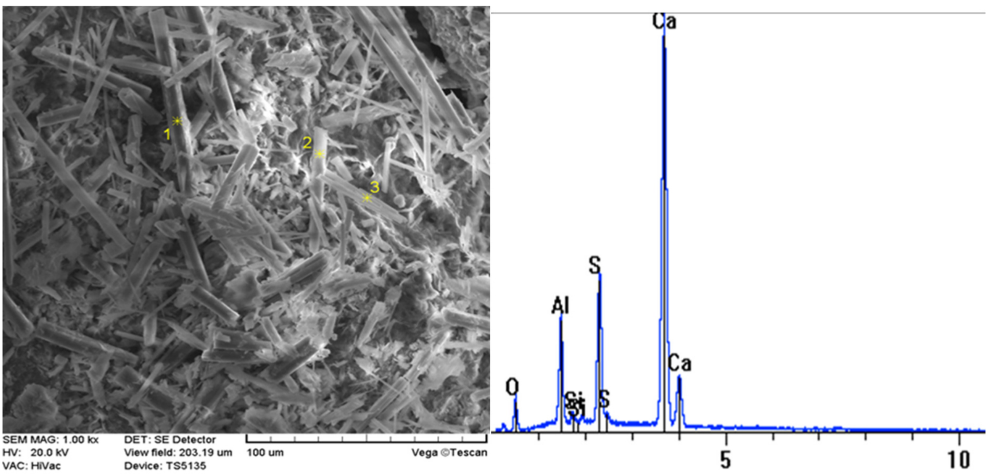


Fig. 16. Analysis of bottom part of floor (sample B) – enlarged left-hand, upper part of photography in Fig. 15 riched in ettringite. X-ray photography, the analysis of elements occurence.

Table 5. EDS. Area 1

Element	O	Al	Si	S	Ca	Total
Line	KA1	KA1	KA1	KA1	KA1	–
Wt, %	36.89	7.57	0.55	12.51	42.48	100.00
At, %	56.84	6.92	0.48	9.62	26.13	100.00

3.3. SEM and EDS analysis of the white efflorescences on the walls and calcium formations (stalactites) on the bottom part of floor

Analysis of wall and bottom part of floor – places with the white dripstones and stalactites presented before in Fig. 4, Fig. 5 are shown as SEM in Fig. 17.

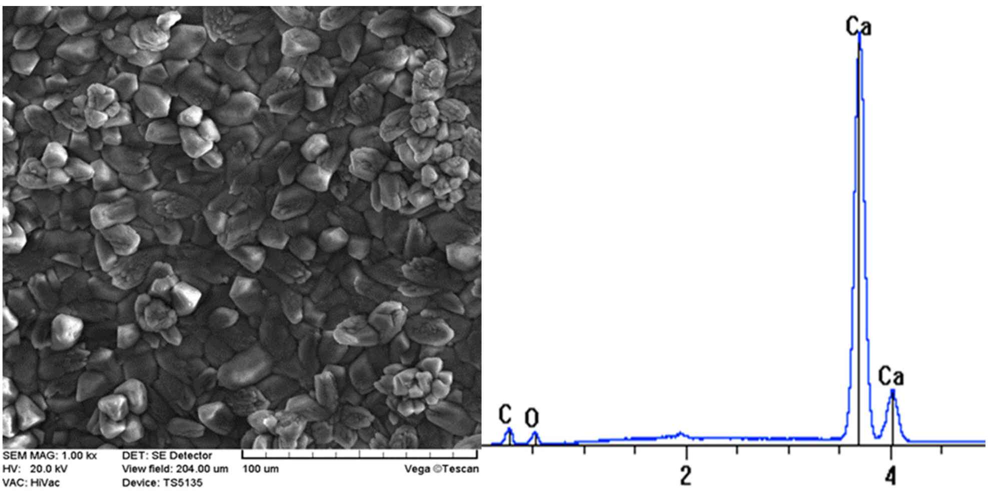


Fig. 17. Analysis of wall and bottom part of floor – places with the white dripstones and stalactites. X-ray photography, the analysis of elements

Table 6. EDS.Area 1

Element	Ca	O	C	Total
Line	KA1	KA1	KA1	–
Wt, %	60.0	17.96	22.04	100.00
At, %	33.60	25.20	41.20	100.00

4. Analysis

4.1. Leaching calcium ions from the concrete structure

The analyzed case of loss of concrete strength as a result of long-term exposure to water is, as shown by the research carried out, with the migration of portlandite. This phenomenon of leaching calcium ions from the concrete structure is described in the literature as a very slow process [13]. The leaching depth of concrete submerged in still water for 100 years was about 5 to 10 mm [14]. To speed up and investigate the state of leaching out of calcium ions over time, accelerated leaching test methods are usually adopted, namely, electrochemical and chemical acceleration methods [12, 13]. Saito H [11] performed leaching tests on different mortars by employing an electrochemical method, which accelerates the dissolution of cement hydrate from mortar in contact with water to apply a potential gradient across the specimen. Jain J., [15] has dealt with calcium leaching from cement pastes incorporating glass powder, silica fume or fly ash by deionized water medium method. The chemically accelerated method was chosen by Cheng, Chao, and Lin [16] with the use of a concentrated ammonium nitrate solution. Planel D., [17] has continuous monitored the calcium loss in pure deionized water and performed the calcium-depleted part of the specimens by microstructure observation. The author of this article, while analyzing the natural Ca^{2+} leaching processes, also came to the conclusion, as did the authors of the above-mentioned publications, that apart from the macroscopic analysis of the samples taken and their current (after 11 years of operation of the tank) mechanical features for documenting the phenomenon, the most accurate analysis of the microstructure of concrete in terms of assessments resulting from XRD, SEM and EDS studies.

4.2. Layered dealkalization of a concrete partition

During observations of the technical condition of the drinking water tank (Figs. 4, 5) the way the concrete was put in the structure was restored: the concrete components were dosed volumetrically and mixed manually, and the mixture was put in layers about 0,5 m thick, the concrete with high plastic consistency was applied. In Fig. 4 and Fig. 5 the delamination in the area of layer contact are visible, since each layer was put after the previous had hardened. Thus, an abruption occurred, as well as the difference in relative air humidity outside and inside the tank caused the migration of Ca^{2+} ions into the inside of the tank, which caused the formation of characteristic white deposits. Migration of calcium compounds caused the dealkalisation of the outer parts of the concrete and increased the vulnerability to corrosion of the reinforcement steel, as well as it increased the porosity of the cement matrix. Similar case of leaching of the cement matrix in buildings, that are over hundred years old and exploited in high relative air humidity, has not been described in any of the quoted bibliographical positions presented in 4.1.

4.3. The stabilizing role of ettringite

Over hundred year old cement matrix presents numerous abruptions of the microstructure, which is a result of the mentioned primitive concrete processes. In that time concrete was concentrated by tamping, which by the high plastic consistency gives the above mentioned effect. In the abruptions the long fibre ettringite can be found, which caused the bridging of the microstructure. It is clearly visible in the microphotograph in Fig. 13 and in EDS analysis (Area 2) which present the upper, carbonised part of B sample. Ettringite is not susceptible to leaching and migration caused by the difference in relative air humidity over and under the ceiling, which is confirmed in the analysis of the lower part of the ceiling presented in Figs. 14–16. The calcium cations are leached, whereas the ettringite "frame" is stable. Carbon dioxide reacting with calcium deposits in the linear or spot form, creates calcium carbonate, which is confirmed in Fig. 17. The described process can be compared to the formation of stalactites in caves found in calcareous deposits of rocks.

4.4. Historical and contemporary concrete

Considering the concrete made and exploited since 1908 and the structural concrete from 2022, it can be assumed that the general oxide composition of both concretes is comparable, and the cement used for production belongs to the Portland cement group without mineral additions. Comparison of the amount of particular elements are presented in Table 7. Especially two problems are worth attention:

– in the concrete from 1908 the presence of sodium and potassium oxides is not observed, which is a sign of dealkalisation of the cement matrix in the structure that has had contact with the environment for 100 years of exploitation; in these areas the concrete is carbonised and strong corrosion of reinforcement bars, as well as the loss of lifting capacity is observed, which is the reason for the cracks in the concrete;
– the composition of the contemporary cements presents an increased amount of oxides MgO, Al_2O_3, SO_3, Fe_2O_3, P_2O_3, at the cost of oxides CaO and SiO_2, which is a result of enriching the clinker with additions coming from the processes of co-combustion of different natural materials which are contemporary energy carriers. It is however hard to say anything about the 100 year durability of those elements.

Table 7. The comparison of cement compositions from years 1908 and 2022

Element	C	O	Mg	Al	Si	S	K	Ca	Sc	Fe	P	Na
1908												
Wt, %	6.73	12.38	0.12	2.37	13.93	0.87	0.00	61.16	1.15	0.94	0.35	0.0
At, %	15.87	21.92	0.14	2.49	14.05	0.77	0.00	43.24	0.72	0.48	0.32	0.0
2022												
Wt, %	22.4	23.01	2.50	5.23	10.15	5.14	0.55	26.92	0.00	2.09	1.64	0.55
At, %	37.73	29.30	2.09	3.95	7.36	3.27	0.29	13.68	0.00	0.76	1.08	0.48

5. Conclusions

The example of the loss of the load-bearing capacity of an over 100-year-old reinforced concrete structure used in drinking water during this period in the drinking water environment presented in the article is, in the author's opinion, an important voice on the durability of concrete. As it results from the cited literature, the strength of concrete changes over the years, and an important factor of changes may be the leaching of Ca^{2+} ions from the cement matrix. The observed phenomenon of portlandite migration towards the interior of the tank with very high relative air humidity ($> 95\%$) results from the diffusion of mass caused by differences in pore liquid concentrations in the layers of the outer and inner partitions. These are slow processes, counted over tens of years of the facility's operation, beneficial – due to the zonal increase in alkalinity – for the protection of steel against corrosion, unfavorable – due to the local increase in porosity and decrease in concrete strength, causing loss of load capacity and the appearance of cracks.

The analyses and observations of the hundred year old concrete in a reinforced concrete drinking water tank are significant guidelines for contemporary projects of closed water reservoirs (such as water treatment plants or swimming pools, etc.): it is crucial to design a tight concrete of class C35/45 at least, from cements CEM I, for example the type SCC; and the protection against humidity penetration in the wall and ceiling structure should be made of special polymer-mineral protective layers.

If a decision is made to revitalize the facility for other new purposes, the walls will need to be repaired and reinforced concrete structures strengthening. Repairs of the historic walls are carried out by specialized companies under the supervision of a conservator. It is best to strengthen reinforced concrete structures by using shotcrete on a steel mesh, as was done during the construction of the museum of the history of Polish Jews in Warsaw [18].

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Degradacja betonu w ponad 100-letniej stacji uzdatniania wody pitnej, przypadek wymywanie wapnia ze zbiorników poddanych długotrwałym obciążeniom wodą

Słowa kluczowe: trwałość, zbiornik betonowy, wymywanie Ca^{2+}, analiza SEM, EDS, XRD

Streszczenie:

Problemy trwałości betonu liczone w dziesiątkach lat nie są częstym przedmiotem badań, mimo że najstarsze konstrukcje wykonane z betonu z cementem portlandzkim mają około 140 lat, a wielkogabarytowe konstrukcje inżynieryjne (takie jak tamy, falochrony), mosty, komory, hale) mają ponad 110 lat. Rozważany zbiornik należy do ostatniej grupy obiektów. W latach 1908-1909 wybudowano stację uzdatniania wody pitnej dla miasta Poznania, które liczyła wówczas 196 tys. mieszkańców. Wodę pobierano bezpośrednio z płynącej obok rzeki Warty. Wymiary obiektu w rzucie wynoszą 65,5 × 21,5 m,

a wysokość powyżej terenu 9,0 m, a poniżej 5,0 m. Jest to perła architektury przemysłowej końca XIX i początku XX wieku, posiadająca najnowocześniejsze wówczas na świecie wyposażenie technologiczne. W części podziemnej na całym rzucie wykonano wielkogabarytowy zbiornik żelbetowy ze stropem żebrowym podpartym pośrodku żelbetowymi słupami. Były to czasy, kiedy powstawały pierwsze na świecie odważne konstrukcje z betonu cementowego, z których niewiele zachowało się do czasów współczesnych. Aby ocenić trwałość betonu po kilkudziesięciu latach oddziaływań wody i bardzo dużej wilgotności względnej powietrza, bardzo istotne jest sprawdzenie zmian w jego mikrostrukturze, które wpływają na jego parametry wytrzymałościowe. Autor badań przeprowadził analizę materiałowo-konstrukcyjną betonu oraz stanu technicznego ponad stuletniej konstrukcji zbiornika i jego elementów. Stwierdzono obniżoną wytrzymałość betonu na ściskanie oraz liczne pęknięcia ścian i stropu, a także duże nagromadzenie białych nacieków w miejscach zarysowań ścian i stropu. Analizy SEM, EDS i XRD wykazały także, że skład fazowy betonu w grubości stropu jest zmienny. W dolnych warstwach betonu obserwuje się stężenie wodorotlenku wapnia, który na zewnątrz przegród zmienia się w węglan wapnia. Migracja portlandytu w kierunku wnętrza zbiornika przy bardzo dużej wilgotności względnej powietrza ($> 95\%$) wynika z dyfuzji masy spowodowanej różnym stężeniem porowatej cieczy w zewnętrznej i wewnętrznej warstwie przegród. Są to procesy bardzo powolne, trwające kilkadziesiąt lat w trakcie eksploatacji zbiornika. Są korzystne ze względu na stopniowy wzrost zasadowości, co chroni stal przed korozją, ale mogą być szkodliwe ze względu na miejscowy wzrost porowatości i spadek wytrzymałości betonu. Zjawisko to zostało opisane w literaturze jako wymywanie jonów wapnia ze struktury betonu. Liczne artykuły z tego zakresu skupiają się na stworzeniu odpowiednio trwałej konstrukcji betonowej poprzez dozowanie odpowiednich dodatków mineralnych, a nie na kilkudziesięcioletnich obserwacjach użytkowanych obiektów. Dlatego też intencją autora artykułu nie było modelowanie procesu ługowania Ca 2+ w laboratorium, ale analiza stopniowej degradacji obiektu przemysłowego poddanego bezpośredniemu oddziaływaniu wody na przestrzeni stu lat.

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