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Asset Management of drinking water reservoirs

FoWa - Research Project: Corrosion and spots on wall

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Substanzerhaltung von Trinkwasser-Reservoirs

FoWa Forschungsprojekt Fleckenbildung und Korrosion

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L'entretien et la rénovation des réservoirs

FoWa-Projet: Corrosion et taches sur les murs des réservoirs

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Introduction

Drinking water reservoirs are important infrastructures to support our population with water. Operational safety and the security of supply of these drinking water tanks must be ensured at all times. The water storage is important for the optimal hydraulic design of the water treatment, the drinking water pumps, main pipes and distribution network. Often the reservoirs are built in concrete as the material properties of the surface are excellent, without affecting the taste or the hygiene of the water during its storage.

The reservoir in general has a life time of 50 to 100 years for the load carrying construction and the water chamber. The coatings may have a shorter service life, depending on the used process and the material. The electronic devices and the hydro-mechanical systems have a life cycle time between 20 to 40 years. For an optimized operation and maintenance of water reservoirs a careful planning and construction is important. For older water reservoirs a periodic inspection of the current state is of great importance. The water quality in the reservoir chamber is an essential aspect. The contact and the influence between the drinking water and the materials as well as the general state of the walls are key factors to analyze. Damages or cracks, corrosion and spots are important marks for a detailed analysis of the chamber.)

Finally, for optimal long-term planning and budgeting of maintenance and repairing work or even the replacement of the reservoir it needs proper knowledge of the actual state of the facility as well as a clear definition of the materials which are in contact with drinking water.

But the practical experience shows, however, that even with careful planning and construction with qualified materials, brown spots may become visible on the cement mortar lined walls within only a few years.

The aim of this research project is to clarify the possibilities of the formation of spots.

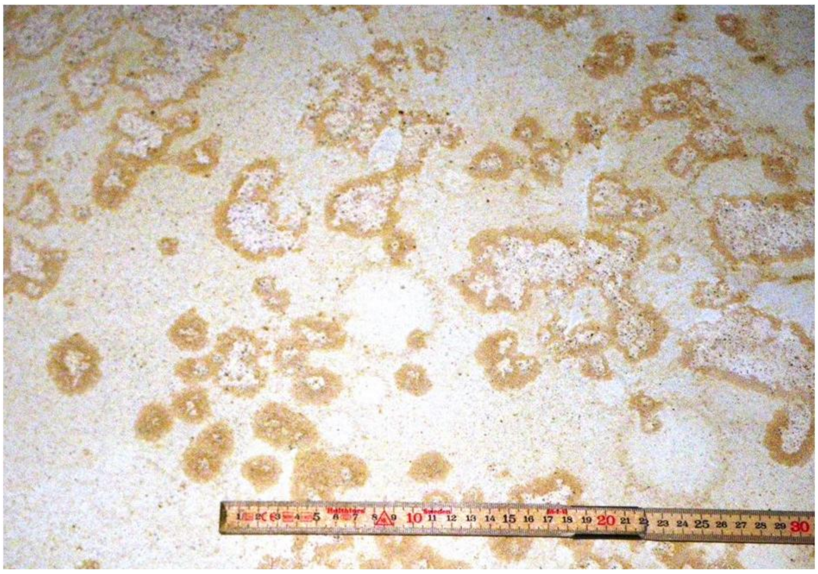


Bild 1 **Fleckenbildung in Reservoirs (70 % Grundwasser/ 30 % Quellwasser pH 7.2**
Formation of brown spots (70 % GW, 30 % SW, pH 7.2, 37 °fH), Picture: SGK

Survey to coating problems in reservoirs

In May 2011, the Swiss water and gas association (SVGW) has performed a survey among its members concerning the topic of the formation of brown spots in water reservoirs. The focus of the survey was on chambers built in concrete, which often have a cement mortar lining. The responsible maintenance staff knew that the formation of these brown spots leads to a softening of the mortar lining, resulting in visual impairment of the appearance of the reservoir chambers. At this time no generally accepted explication for the process of the formation of brown spots was known.

111 water supply companies followed the survey. These companies operate 530 reservoirs, whereof 128 reservoirs had damages or spots. Based on this survey the Swiss water and gas association planned this research project in cooperation with the Swiss Society for Corrosion Protection (SGK), the Technical College of Rapperswil (HSR) and the Zurich Water Supply which was mainly founded by the members of the Swiss water association.

Research Project FoWa (Forschungsfond Wasser SVGW)

In summer 2012 the FoWa commission allowed the project application and technical description. The project was founded with CHF 120’000.-. The project was managed by SGK, the partners worked on the subprojects independently.

The results below are documented in the final project report. The results were mainly worked out by the partners SGK and HSR. A detailed report is published in the Journal Aqua & Gas / 2015-6.

Aim of the project

At this time various possibilities and causes for the formation of spotting in reservoirs were discussed. Experts assumed the influence of microbiological growing on the walls, hydrolysis and water pressure differences in the concrete. But none of these causes led to a solution of the problem. The aspect of corrosion processes and not in detail known ion transport processes are possible reasons for this process.

The following questions were discussed in the project.

- Can steel corrode in healthy concrete due to different electrochemical potentials?
- What possibilities exist to prevent corrosion?
- What is the impact of current to the formation of spotting?
- What is the influence of the water quality?
- What are the options to reduce the formation of spotting?

Used concrete for the experiments

The team used different types of concrete. The samples were produced with different water / cement ratios (0.47 and 0.60). They also used two different cement qualities (CEM I) regarding older constructions and new reservoirs (CEM II) with higher quality standards for materials in contact with drinking water.

Project results

Influence of water quality

Water samples and samples directly at the spots were taken in the reservoirs. The samples were analyzed in order to find correlation between the water composition and the spots. 10 reservoirs were included in the study, of which a few used UV or chlorine for water desinfection. Primarily reservoirs with ground- and spring water or sometimes mixed water were analyzed. In 9 reservoirs calcite sedimentation was found. The pH-value was very similar between pH 7.2 to pH 7.5 and the water was nutrient-poor. A visible biofilm was found only at a few rehabilitated parts on the walls or on the bottom of the reservoirs.

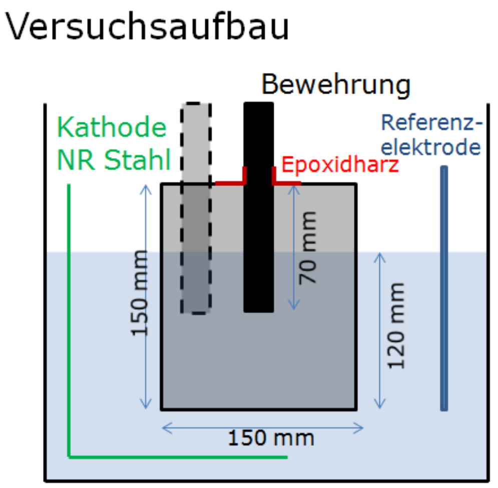
Reservoir / Community	SI	Sulfate (mg/l)	Chloride (mg/l)	pH	Hardness (°fH)	KH (mmol/l)	T (°C)
Feument M.	0.19	14.4	19.6	7.2	37	3.46	10.3
Dachsberg E.	0.11	23	17.9	7.3	34	2.91	9.6
Sternen B.	0.16	8	16.5	7.4	26	2.44	11.5
Unterberg H.	0.28	12	10.3	7.3	39	3.53	9.6
Reitenbach F.	0.18	7.7	9.8	7.3	36	3.39	8.3
Hiltenberg M.	0.11	13.2	10.0	7.2	34	3.30	10.3
Belvedère B.	0.12	17.9	25.4	7.3	32	2.83	12
Sören N.	0.35	18.6	10.2	7.5	34	3.07	7.9
Eichholz B.	0.33	14.6	9.7	7.5	33	3.06	6.5
W.	-0.12	0.7	2.0	7.7	12	1.21	8.6

Tabelle 1 **Übersicht der wichtigsten chemischen Qualitätsparameter im Vergleich**
Overview of the main chemical water quality parameters in comparison / WVZ

With one exception, all analyzed water samples were similar in their chemical mixture and pH-value and rated as not critical for corrosion of concrete. Due the drinking water analysis no significant correlation between water quality and the formation of spots could be confirmed.

Corrosion of steel in concrete

An experiment was set up in the laboratory of SGK. The goal was to investigate the characteristics of corrosion of steel (reinforcing bar) in concrete by macro element corrosion.



Referenzelektrode	*reference electrode*
Kathode NR Stahl	*stainless steel, cathode*
Bewehrung	*reinforcement*
Epoxidharz	*epoxy layer*

Abbildung 1 **Versuchsaufbau für die Makroelementkorrosion, Skizze SGK**
Experimental setup for macro element corrosion simulation

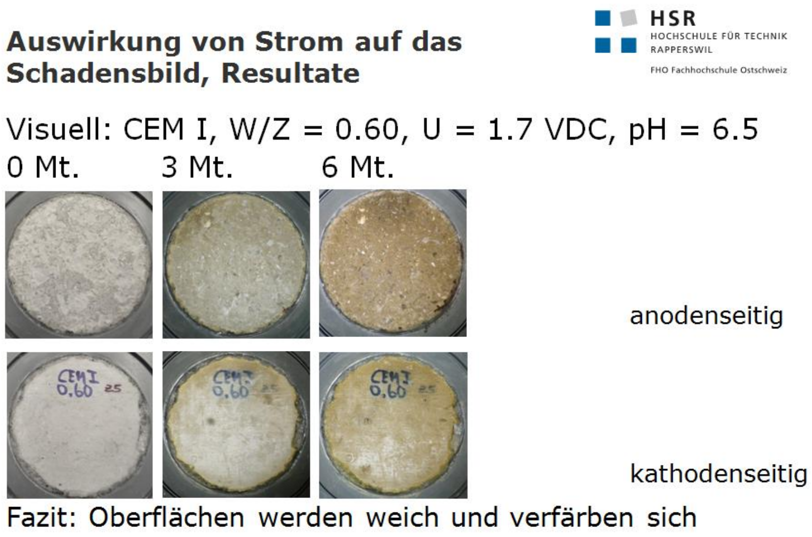
The results show that the corrosion has stopped on all concreted rebars. The time until the corrosion stops depends on the used concrete quality for the four concrete cubes (cement CEM I and CEM II, water/cement ratios 0.60 and 0.45).

There is no corrosion if the reinforcing bar is properly bedded in concrete even with an electrical contact to stainless steel. Due to the inhomogeneous concrete structures and quality defects during concreting on construction sites, an electrical isolation of the metals is recommended and helps to prevent damages.

Direct Current (DC) effect on the damage

Some completely in water soaked concrete disks were exposed to a defined direct current (DC). Possible changes on the disks were visually documented.

The most important result of the experiment was a visual change on the surface. At locations with a stray current entry to the surface a thin calcite layer was detectable. Regarding locations with a stray current exit, a softening of the surface was found. The calcium hydroxide was dissolved from the concrete and mortar layer. This process is in relation to the DC density.



W/Z	*Water / cement ratio*
CEM I / CEM II	*Definition of cement quality*
anodenseitig / kathodenseitig	*the anode side / cathode side*

Abbildung 2 **Einfluss von Strom auf das Schadensbild, mit tiefem pH 6.5, Bild HSR**
Influence of direct current (DC) to the surface of the concrete samples, pH 6.5

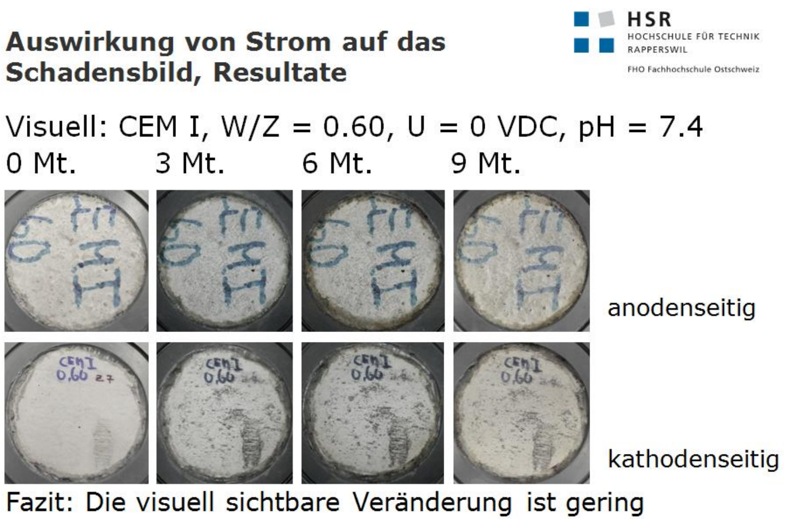


Abbildung 3 **Einfluss von Strom auf das Schadensbild, leicht kalklösend (pH 7.4, alkalisch), Bild HSR**
Influence of direct current (DC) to the surface of the concrete samples, pH 7.4, alkaline

Results

For a current flow, a voltage gradient is needed. The tests and the measurements show, that the different humidity and pH gradients produce a voltage gradient, thus damages on the surface are possible.

According to the research report this result is a possible explanation for the formation of spots. The current entry creates a protecting calcite layer on the surface. The electric resistance increases and causes a better durability of the surfaces. These positives effects, which also occur after the installation of a cathodic protection system, can now be explained. Furthermore the CP causes an increase of the pH at the reinforcement which will become passivated.

Conclusions

The research work was done under ideal laboratory conditions at the partners. External influences such as temperature, homogeneity of the concrete and stray current conditions were constant, uniform and continuously recorded. These laboratory conditions may be transferred to the practice only with certain limitations. Often the working conditions on a construction site are not comparable to the laboratory.

However, the results of this research project show that a stray current exit may cause damage to the concrete. A stray current entry causes a thin calcite layer on the concrete. This layer protects the reinforced concrete. A reliable electrical isolation of the metallic elements reduces the stray current and protects the concrete structure. A correct concreted reinforcement is protected against corrosion. The pH value of the water has an effect to the damage and the formation of spots. With decreasing pH, respectively, higher CO_2-value, the water is more aggressive and the surface of the walls is more attacked.

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