Application of the conductivity sensor as a chloride detector in concrete

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Abstract

Concrete structures being exposed to chloride bearing solutions such as seawater or de-icing salts brine can undergo deterioration due to the corrosion of the reinforcing steel. In order to monitor the chloride ingress into concrete chloride sensors could be embedded in concrete. However, the commercial availability of such sensors is still very limited. Therefore, the common practice is to extract samples from the existing concrete elements for the determination of the chloride concentration profiles. Besides the fact that this procedure is invasive, it is also time consuming and costly and thus, the market demands better alternatives.

This article investigates the possibility of using a conductivity sensor as a detector for chlorides in concrete. Chlorides present in the concrete pore solution change its chemical composition and in turn also the conductivity. In the present study, the output signal of the sensor is analyzed for different additions of chlorides into concrete. The results show that there is a potential of using the conductivity sensor for detecting the chloride level.

1. Introduction

Maintenance of concrete elements and structures consumes significant amount of effort and finances. Among the various concrete deterioration mechanisms, the deterioration of concrete caused by the action of chlorides on the reinforcing steel is very common. Therefore, there is a practical need of monitoring the chloride penetration level inside concrete to take the necessary remediation steps (e.g. surface coating or chloride extraction) on time, before the corrosion occurs and causes severe consequences, including the demolition of the structure as the worst case scenario.

Sensors sensitive to chlorides could provide very crucial information on the chloride penetration level into the concrete structure. Currently the research focuses on two main types of in-situ chloride sensors for the use in concrete, including the system of a chloride-selective electrode coupled to a reference electrode (e.g. [1, 2]) and the optical

sensors (e.g. [3, 4]). However, both these types of sensors have certain drawbacks, such as their poor long-term durability in the alkaline environment of the concrete pore solution, high interference of the hydroxyl ions on the chloride-selective electrode and the low reliability of their long-term output signal. Hence, with these drawbacks, the practical use of chloride sensors in concrete is very limited and usually other monitoring methods are preferred, including the invasive extraction of cores for the analysis of the chloride penetration depth.
Therefore, there is a need for the development of reliable and durable chloride sensors.

2. Conductivity sensor

Chlorides entering the pore solution of concrete change its electrical conductivity; thus, this type of sensor is investigated in this study as a chloride detector. A commercially available conductivity sensor is used here (ConSenor B.V., the Netherlands). The probe has two electrodes between which a sine wave voltage (frequency of 150 kHz) is applied. Due to the applied voltage a current flows through the concrete, depending on its conductivity (inverse of the resistivity). The sensor is connected to a data logger, which transmits the output signal via GSM to the database. The sensor and the data logger are shown in Fig. 1.

Fig. 1: Data logger (left-hand side) and conductivity sensor (right-hand side)

3. Experimental plan and test results

Standard mortars (according to the definition given in [5]) are prepared in this study, using different addition of chlorides, i.e. 0% (reference), 0.25%, 0.5%, 0.75%, 1% and 1.25% of chlorides by the total mass of mortar. Calcium chloride ($CaCl_2$) is used as the source of chlorides. After mixing, the mortar is cast into 10 cm cubes and the sensors are

embedded in the moulds vertically. In order to accelerate the hydration of cement, a climate chamber treatment is applied (a constant temperature of 40 °C and 100% RH). The conductivity of the mortars is measured continuously until a constant value is reached (completed hydration of cement), which takes about 10 days in all the analyzed cases. After the curing period, the free chloride concentrations in mortars are measured, following the description given in [6].
As an example, the development of the conductivity of mortar in time is presented in Fig. 2.

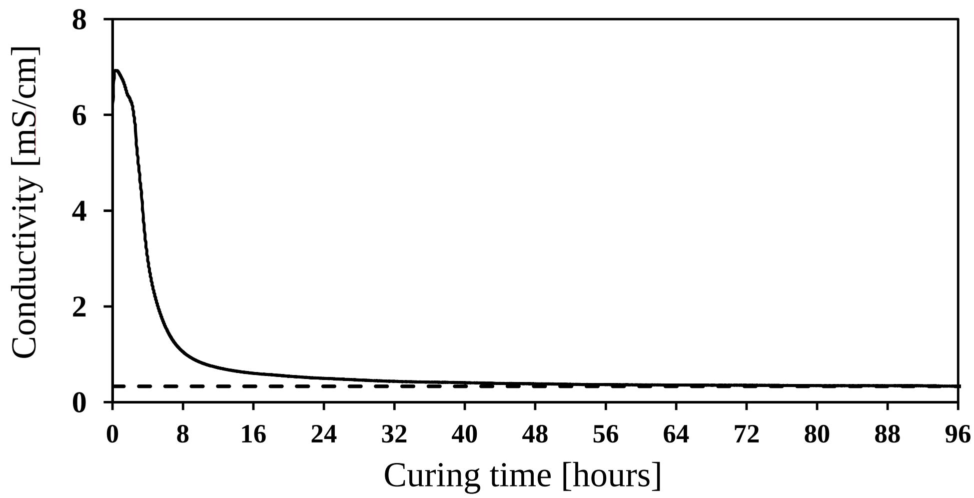

Fig. 2: Development of conductivity of mortars in time

The measured final conductivities of the mortars are plotted in Fig. 3 against the determined free (water soluble) chloride concentrations.

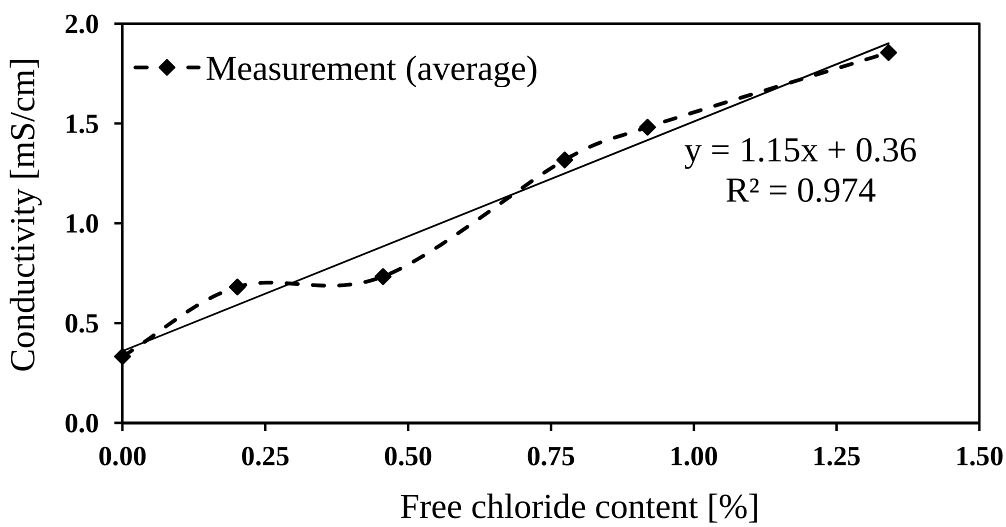

Fig. 3: Conductivity of mortars vs. the free chloride content

4. Conclusions and plan for the future work

This preliminary study shows that the conductivity of mortars can be linearly correlated to the free chloride concentration (Fig. 3). Thus, potentially, the employed conductivity sensor can be used for the detection of chloride in concrete.
The upcoming research will focus on the utilization of the sensor for the detection of chlorides penetrating into the concrete initially free of chlorides. This will be analyzed in two different ways, including the electrically accelerated chloride ingress (high chloride penetration rate to shorten the experimental period) and natural diffusion (long term tests, to analyze the durability and reliability of the sensor).

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