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Betrifft:
Concerne: **Field test with Protectosil ® CIT**

Auftraggeber:
Commettant: Degussa AG

Auftrag vom
Ordre du

Messungen vom
Mesures du 5.12.01.-1.3.04

1. Task

The effectiveness of the corrosion inhibitor Protectosil ® CIT by Degussa AG, Rheinfelden, has been investigated in a field test.

2. Situation

The characterization of the effectiveness was tested by means of corrosion sensors embedded in concrete. The corrosion behavior was investigated with a continuous data acquisition system. Hence, the effectiveness of the corrosion inhibitor was determined as a function of time, the climatic conditions etc. The test was performed on existing columns of the gallery Cianca Presella on the Swiss Highway A13 near the San Bernardino tunnel.

3. Measurements

3.1 Experimental set-up

The setup of the sensor elements is shown in Fig. 1. Each of the elements contains 3 rebars, which are used as corrosion sensors. The concrete cover is 10 mm. Hence a fast transport of the aggressive substances can be achieved. For the chloride containing sensor elements, the corrosion potential of one sensor, and the corrosion current between the two other sensors and the rest of the reinforcement mat in the col umn was registered. In the case of the chloride free sensor elements, the corrosion potential was recorded. The measurement of the corrosion potential allows to determine the corrosion initiation, while the monitoring of the macrocell corrosion current enables the measurement of the corrosion rate.

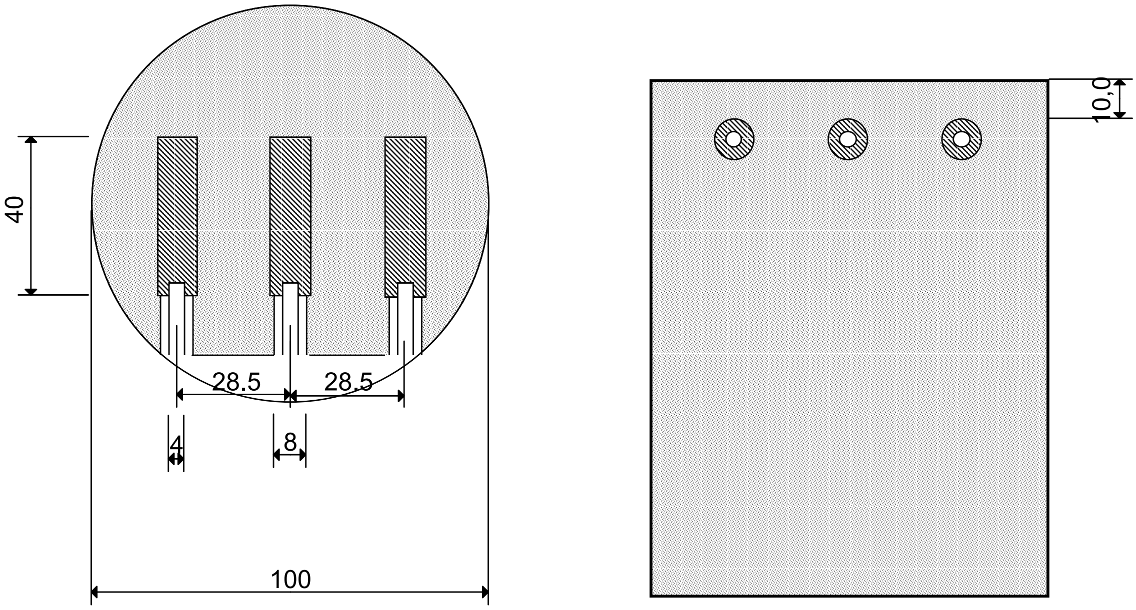

Fig. 1: Construction of the sensor elements with 3 rebar sensors

The used sensor elements and their treatment are shown in Table 1.

Table 1: Sensor elements

Sensor element #	Chlorides	CIT Treatment	Column
1	X	X	A
2	X		B
3		X	A
4			B

Two sensor elements (sensors elements1 and 2) were soaked with 2 M NaCl solution in order to evaluate the corrosion behavior of an existing structure with already existing corrosion damage.

All elements were then exposed to a relative humidity of 75% for 4 months. Two days prior to the treatment the humidity was lowered to 40%. Two sensor elements (1 and 3) to be built into columns of the gallery Presella were pretreated with PROTECTOSIL ® CIT. 2 g of PROTECTOSIL ® CIT was applied on both of these sensor elements in two coats, according the manufacturers instructions, on the surface exposed to the environment. This equals an amount of 0.5 kg/m^2. Then the ele ments were stored at 80% relative humidity. All sensor elements were installed on the 14th of January 2002 at the gallery Presella (Fig. 2) and the measurement was started immediately. The elements were installed in different columns (see table 1). Therefore, no interaction of the PROTECTOSIL ® CIT treatment on the results of the non-treated sensors was possible. Within the first six months no significant difference in the corrosion behaviour between the treated and non-treated sensors was observed, since only the sensor elements were treated**.** Any effect of the PROTECTOSIL ® CIT on the cathodic reaction was not possible to detect under the given configuration. Therefore, on the 7th September 2002, the entire surface of the column containing the sensors pre-treated with the PROTECTOSIL ® CIT was coated with PROTECTOSIL ® CIT according to manufacturer instructions. In doing so, the anodic and cathodic reactions are now considered in the configuration, as it is the case in any field application.

Fig. 2: Gallery Presella at the A13. The sensors are installed in the columns on the right.

3.2 Results of the Gallery Presella

The results of the investigation are presented in the Fig. 3 to 6. In Fig. 3 the corrosion currents are displayed. Starting from low temperatures in January 2002 the corrosion current continuously increased in spring. This effect is primarily a result of the increased concrete conductivity in the warmer season. Additionally, the strong effect of the daily temperature cycles is visible. In general, the sensors with PROTECTOSIL ® CIT treatment show a slightly smaller corrosion current compared to the non treated sensor element. In fall 2002 the decreasing temperatures result in a decrease in the corrosion current for all sensor elements. As the effect of the Protectosil CIT treatment was not yet significantly visible (only anode area treated, i.e. the sensor), the entire column was treated with Protectosil CIT (anode and cathode areas covered). During winter 2002/2003 clearly higher corrosion currents were observed for the sensors without treatment. The increasing temperatures in spring 2003 result again in an increase in corrosion current for all sensors. However, the increase is smaller compared to summer 2002. This is probably related to the extraordinary dry conditions experienced during this period, which caused an increase in concrete resistivity. Based on the experience of other structures, also an effect of the corrosion products formed on the steel surface may have an effect on the decreased corrosion rates. In fall 2003 the current decreases again following the decrease of temperature. For the sensors treated with PROTECTOSIL ® CIT very low currents are observed. In one case even the repassivation of the originally corroding sensor takes place (label p in Fig. 3). In the case of the non-treated column, reactivation of the sensors takes place. It can be surmised that water and additional chlorides from deicing salts are transported to the sensor elements increasing the aggressiveness of the environment, causing the reappearance of active and significant corrosion (label a in Fig. 3).

For a more detailed analysis the current flow was integrated and from the electrical charge the amount of corroded steel was calculated. This allows to estimate the development of the corrosion damage. The results of two representative samples are shown in Fig. 4. The sensor with PROTECTOSIL ® CIT treatment shows a smaller increase of the steel dissolution within the investigated time range. Further, the slope of the mass loss curves is smaller after the second PROTECTOSIL ® CIT treatment in September 2002. During fall 2003 the curve with the PROTECTOSIL ® CIT treatment clearly flattens to reach a level corresponding to a passive surface (label p in Fig. 4). During the same period a reactivation of the corrosion process is observed for the untreated sensor (label a in Fig. 4).

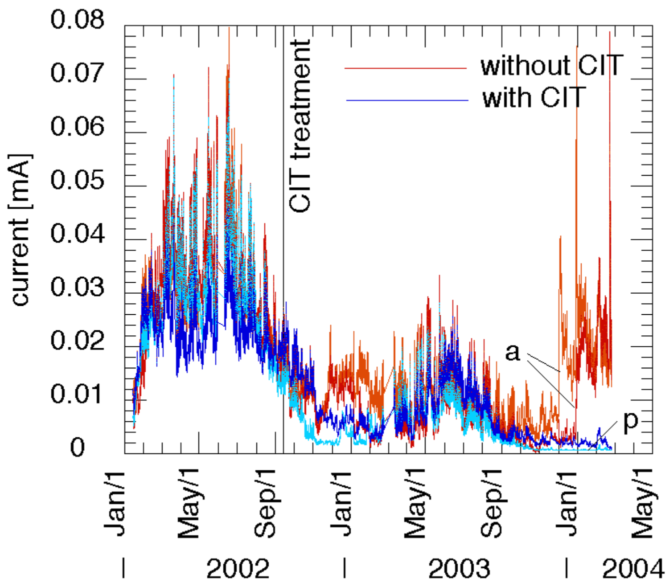

Fig. 3: **Corrosion current of the chloride treated sensors. The label "a" stands for activation and the label "p" stands for repassivation.**

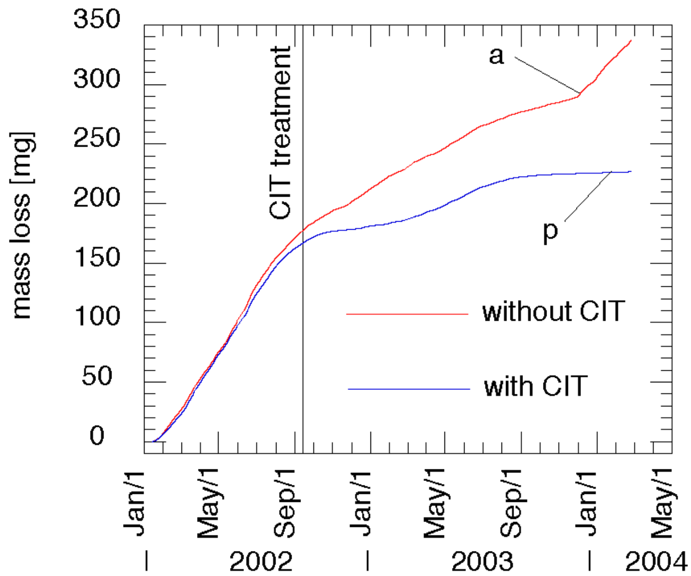

Fig. 4: **Mass loss calculated from current data of sensors in Fig. 3. The label "a" stands for activation and the label "p" stands for repassivation.**

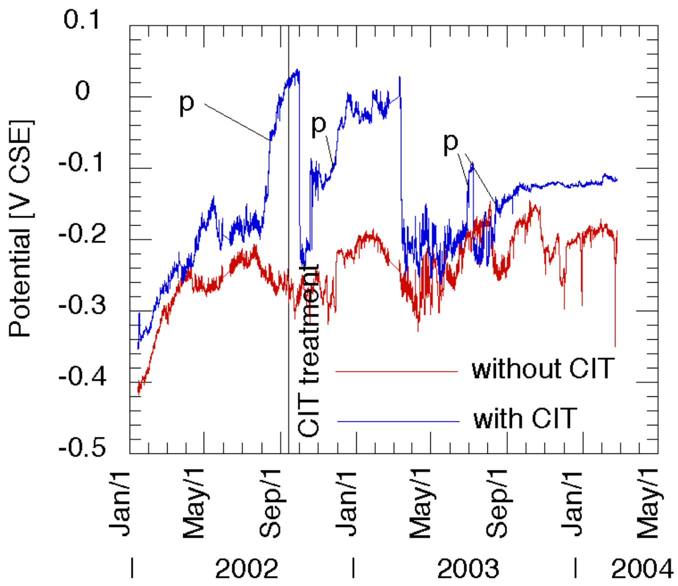

Fig. 5: **Corrosion potential of the chloride treated sensors. The label "p" stands for repassivation.**

Based on the development of the corrosion potential of the sensors it can be concluded that the sensor with PROTECTOSIL ® CIT treatment repassivated repeatedly (labels p in Fig. 5), while the non-treated sensor remained in the active corrosion state. The stable potential of the sensor with PROTECTOSIL ® CIT treatment since August 2003 is an indication for repassivation, while the non-treated sensor is still active. The results obtained for the sensors with chloride contamination and active corrosion showed repassivation processes or at least decrease of the corrosion rate after treatment with PROTECTOSIL ® CIT.

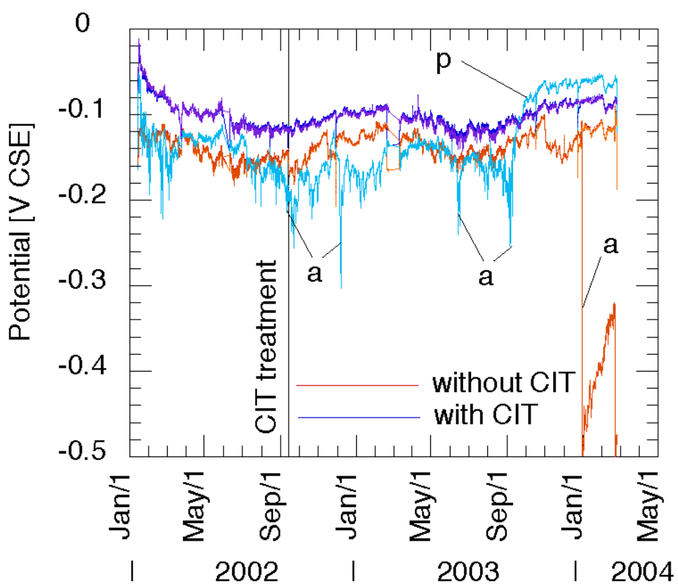

Fig. 6: **Corrosion potential of chloride free sensors. The label "a" stands for activation and the label "p" stands for repassivation.**

In Fig. 6 the results of chloride free sensors installed in the columns of the gallery Presella are shown. Immediately after installation one of the treated sensors (bright blue) showed some slight corrosion activity. During fall 2003 the passivation of the sensor is observed in agreement with the repassivation processes observed on the chloride contaminated sensors with PROTECTOSIL ® CIT treatment. In January 2004 the clear activation of corrosion is observed for one of the three sensors without treatment. Chloride transport from the concrete surface resulted in sufficient concentration to initiate corrosion (label a in Fig. 6). In the case of the sensors with PROTECTOSIL ® CIT treatment no corrosion initiation is observed (label p in Fig. 6).

4. Conclusions

Based on the data available to date the following conclusions are possible:

The Protectosil CIT treatment resulted in a clear decrease in corrosion current, and even repassivation is observed on the sensors initially showing active corrosion.

The initiation of the active corrosion is prevented in the case of PROTECTOSIL ® CIT treated sensors showing passive behaviour.

The use of the PROTECTOSIL ® CIT causes repeated repassivation of an active corrosion sensor as can be concluded from the corrosion potential data.

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