Modular corrosion measurement system (CMS) for electrochemical NDT

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Introduction
Combination, comparison and application of electrochemical methods to evaluate the state of corrosion of reinforcing steel, taking the condition of concrete into account, in principle have been demonstrated in the past. In this contribution, a modular corrosion measurement system (CMS) for the determination of electrochemical parameters of the concrete as well as of the steel reinforcement is introduced. The system possesses a specialised measurement and control device, an electrochemical measuring cell with a multi electrode assembly to be used for surface measurements and for measurements to characterise the concrete steel and an application software to analyse and interpret the experimental data with the objective of an estimation of corrosion conditions of reinforced concrete.

Electrochemical measuring cell
The combination measuring cell (CMC) (Fig.1) that can be positioned on the surface to be evaluated is designed both for a time-resolved use at user-selected points and for space-resolved laminar investigations. It forms a composite-arrangement of metal and concrete which can be used independent of position. Compared to an Ag/AgCl, KCl-based electrode with an epoxy or polyester resin, filled with KCl as ionic conductor and special internal electrolyte for different climatic conditions were developed. A polymer electrode the solid state reference electrode shows potential differences < 5 mV when the metal electrodes are interconnected. For the application within the CMS, position independent reference electrodes with special internal electrolyte for different climatic conditions were developed. A polymer based electrode with an epoxy or polyester resin, filled with KC1 as ion conductor and containing an Ag/AgCl reference element, represents a novel solid state reference electrode which can be used independent of position. Compared to an Ag/AgCl, KCl-based electrode the solid state reference electrode shows potential differences < 5 mV when combined with different measurement solutions.

Methodical studies with the CMC
By combination of several measurement methods with a specialised potentiostatic system and the application of these methods in parallel using the novel combination measuring cell, on the one hand it is possible to optimise the methods by variation of parameters and on the other hand to interpret different measuring values per measuring position in a comparative manner. In Table 1 the measuring process at one point of the CMC. The determination of the polarisation resistance R can be carried out by analysis of the adjustment behaviour of the galvanostatic polarisation potential U = U - U (Fig. 4A) or by analysis of the slope of the potentiostatic current-potential curve in the range around about ±50 mV of the corrosion potential (Fig. 4B). It is remarkable that (concerning the determination of the polarisation resistance R, by regression analysis with a model according to Fig. 4C) comparable results to the galvanostatic pulse method could be achieved by using an IR-compensation in the process of the potentiostatic polarisation.

Specialised measurement and control device
A recent structure with pre-located impedance converters to minimise the influence of electromagnetic disturbance, a module for measuring surface and concrete resistance and a potentiostatic/galvanostatic module to perform complex measurements of different electrochemical methods are the core of a complex, modular measurement and control system. The control unit, consisting of an embedded PC, is responsible for the correct connection of the modules to the cell, depending on the selected measurement principle and also for the communication to the modules via a CAN bus. Simultaneously, the embedded PC unit records, analyses, reduces and stores the data for access by the external evaluation system. Communication is done via an Ethernet interface with a special protocol, placed on the TCP / IP protocol. The system also operates independently without additional power supply, therefore a battery pack and a charging system were implemented.

Procedures for the complex analysis and interpretation of the measurement data
It was the aim to enable also operators who are not specialised in corrosion science, to run a corrosion survey with sound results and safe interpretation. This includes also cases where no definite interpretation can be given - caused either by unsafe measurement conditions or by uncertain internal assessment results. It is intended to close the usual gap between data measurement and their logical and mathematical interpretation within one system. As a result of the internal data processing, not only the measurement results themselves are provided and displayed, but also information about the status of corrosion activity - for a complete grid of survey. A logical data comparison helps to find the appropriate result or states uncertainties, if contradictions arise. More detailed information to evaluate even the speed of corrosion can be received from polarisation measurements, which are also included in the system.

Conclusions
A new corrosion measurement system, consisting of a combination measuring cell and a network-compatible modular measurement and control system is introduced to evaluate the surface of concrete and the corrosion status of reinforcement. Complex analysis of raw measurement data by internal processing with data comparison enables their logical and mathematical interpretation within one system.

References

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