DEVELOPMENT OF METHOD FOR ASSESSING EFFICIENCY OF ORGANIC CORROSION INHIBITORS IN CONCRETE REINFORCEMENT

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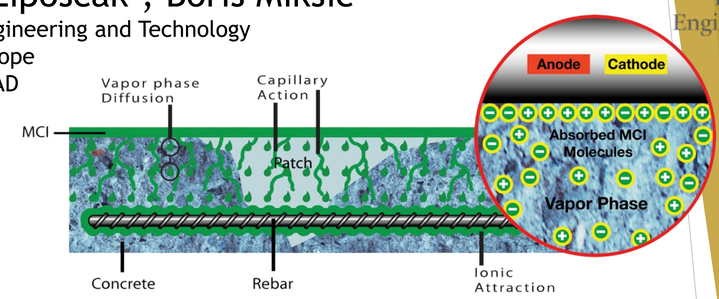
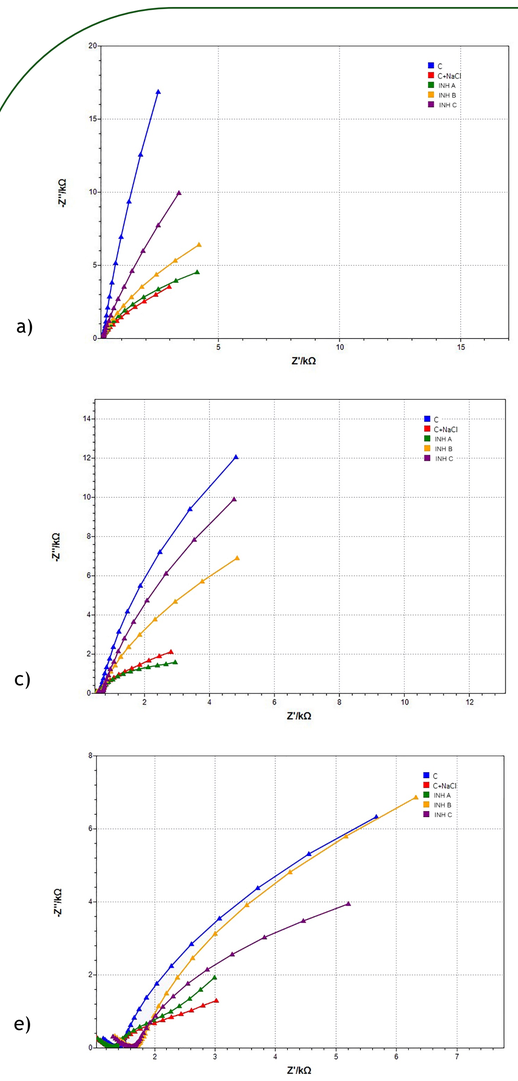


MIGRATING CORROSION INHIBITORS

Introduction

The corrosion of reinforcement steel is the most common cause of premature deterioration and shortening of the lifetime of reinforced concrete structures. Under normal operating conditions, concrete is not an aggressive corrosion environment for steel. Steel corrosion in concrete occurs if concrete is not of a suitable quality, if structure is not properly designed for aggressive exposure, if the environment is more aggressive than provided for in structural design, or if it changes during the lifetime of the structure. The applicability of electrochemical impedance spectroscopy in a cell consisting of a steel plate covered with concrete layer containing chlorides and inhibitor, constructed in accordance with HRN EN ISO 16773, is studied for the first time in this paper. The measurements have enabled quantification of harmful chloride action and inhibitor efficiency, understanding the mechanism and time dependence of inhibitory activity, and visual inspection of metal surface after measurement. The results are consistent with the presumed physical model and point to the applicability of the method.

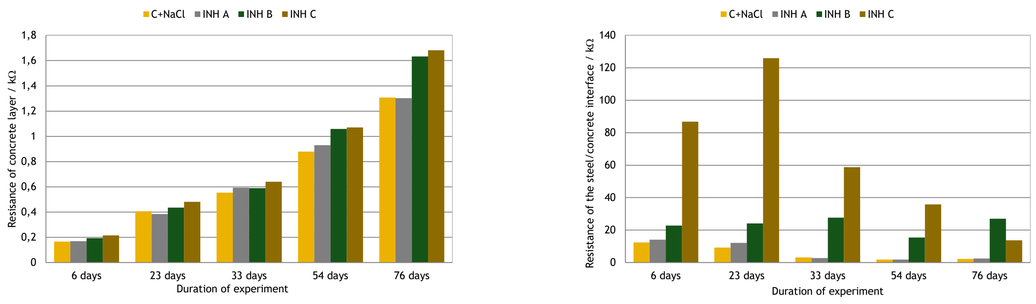


Impedance spectra in Nyquist plot for different systems after a) 6 days, b) 23 days, c) 33 days, d) 54 days and e) 76 days.

In Fig. a to e, which show the metering results, only semiconductor parts are visible, and model parameters are obtained by adapting the model with metering data. The maximum impedance of the steel/concrete interface is exhibited by a sample without additives (C), and the smallest impedance by a sample with NaCl without inhibitor (C + NaCl). Middle impedance values are observed in samples of INH C and INH B, while as to inhibited samples, the lowest impedance value is exhibited by a sample with INH A inhibitor.

The impedance of all samples changes over time. Samples with INH B and INH C retain a relatively high impedance values throughout the test. Diffusion influences occur in systems with chlorides only, without inhibitors at all exposure times and with inhibitor INH A and chlorides for longer exposure times of ≥ 33 days. The same samples have very low impedance values throughout the test.

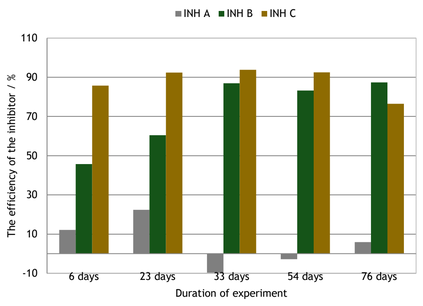
Histograms of resistance in systems



The first histogram reveals a change in the resistance of the concrete protective layer, which increases with time. The values of concrete layer resistance of samples are close, but the last measurement shows a significant increase in resistance for samples with inhibitors INH B and INH C.

By comparing the two histograms, it can be observed that the total resistance is dominated by the resistance of the steel/concrete interface, and it can therefore be assumed that this resistance also reflects the activity of the inhibitor. Systems with the addition of INH B and INH C exhibit extremely high resistance of the steel/concrete interface, which is considerably higher than the resistance of the control sample with and without the addition of chlorides.

The efficacy of the inhibitor system



$$\eta[\%] = \frac{R_0^{-1} - R_{INH}^{-1}}{R_0^{-1}} x100$$

R0 - steel/concrete interface resistance in the non-inhibitor system
RINH - system with inhibitor

The histogram shows that inhibitors INH B and INH C are very effective in preventing corrosion of the steel substrate, and that their efficacy elapses with time. The effectiveness of INH A, unlike INH B and C, oscillates around zero.

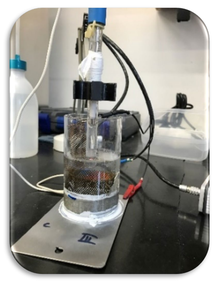
Oscillations can be explained by passivation and depassivation of surface portions, which is a characteristic behaviour of steel surface in the partially passivating environment.

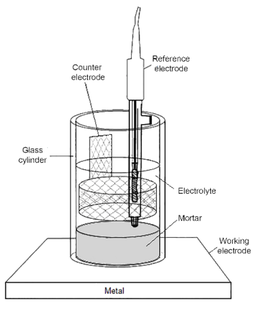
The efficacy value averaged over the entire study period is 90.9 % for INH C, 70.9 % for INH B, and 5.6 % for INH A. Relatively stable values for highly effective B and C inhibitors are seen to occur after 33 days, which enables shortening of the experiment implementation time. This time is much shorter than the one normally required according to the ASTM-G109 method.

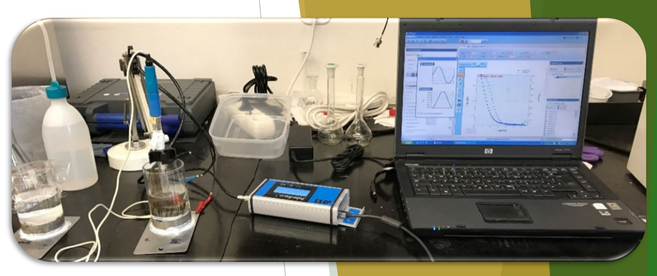
MIGRATING CORROSION INHIBITORS
FROM GREY TO GREEN

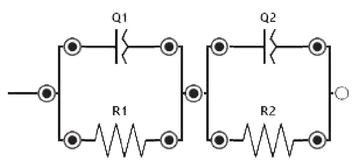
MCI 2005NS (A) **MCI 2006NS (B)** **MCI 2005 (C)**

Cortec® Corporation's patented MCI® (Migrating Corrosion Inhibitor™) Technology protects reinforcing metal in concrete from corrosion. MCIs are based on amine technology (amine alcohols and amine carboxylates). They are classified as mixed inhibitors, meaning they affect both anodic and cathodic portions of a corrosion cell. When MCI® comes in contact with embedded metals, it has an ionic attraction to it and forms a protective molecular layer. This film prevents corrosive elements from further reacting with the reinforcement and also reduces existing corrosion rates, greatly extending concrete service life.









Electrochemical equivalent circuits used for impedance measurement

Steel plates immediately after removal of cylinders with concrete

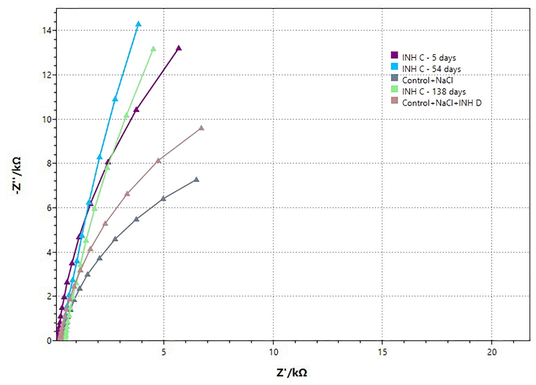
C C+NaCl INH A INH B INH C

Steel plates one month after removal of cylinders with concrete

INH A INH B INH C

Steel plates two month after removal of cylinders with concrete

Newer measurments



The newer measurement are based on the exposure of steel plates with and without INH C for longer period and it is still in progress.

Impedance spectra in Nyquist plot is showing much higher impendance values of system with INH C through 138 days in comparation with average impedance value of control in the same period.

The setup contains two equal controls. After 134 days one was emptyed, dried and coated with INH D.

4 days later, measurment showed significant improvement in impendance values between control and control with addition of INH D.

Conclusion

This paper investigated the possibility of testing effectiveness of corrosion inhibitors in concrete by adapting the standard method HRN EN ISO 16773 to the required purpose. The specific construction of the measuring cell enabled activation of impedance spectra, from which conclusions can be reached about:

- the mechanism
- the efficiency
- the time dependence of the inhibitor efficiency
- the visual inspection of the metal surface can be completed upon completion of the measurement.

Three organic corrosion inhibitors were tested. Based on the research, it can be concluded that the migrating INH C inhibitor is most effective in corrosion inhibition (average efficiency value is 90.9%), and its efficacy does not change significantly over time. INH B also has a high steady average efficiency value of 70.9%, and the last measurement shows almost identical behaviour of the system with chlorides and INH B and pure mortar systems without the addition of sodium chloride. Inhibitor INH A shows an increase in efficacy at the initiation of measurement of up to about 20%, but later its efficiency decreases, only to increase once again at the end of the measurement (average efficacy value is 5.6%). It was found that the presence of chlorides in concrete most reflects on the resistance of the steel/concrete interface, that is, exactly where the corrosion inhibitor is active. The speed of testing and the possibility of quantification of inhibitory efficacy are the main advantages of the tested method prior to the prevalent ASTM-G109 method which, most likely due to its slowness and its qualitative nature, has not found its place in European standardization practice.