EIS Approach to Determine Potential Reactive Chemicals Causing Alkali-Silica Reaction in Concrete

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Abstract: In this study the bulk resistance of selected concentrations of sodium hydroxide, calcium hydroxide, sodium silicate, water and a mix of all the solutions were determined using the Electrochemical Impedance Spectroscopy (EIS). The Bode plots for the selected one liter solutions in the frequency range from 0.1 Hz to 1000 Hz were obtained to determine the bulk resistance which was in the range of 70 to 150 k-Ohm. Also the conductivity of the solutions were measured and related to the bulk resistance.

1. Introduction

Alkali Silica reaction is one of the most occurring deleterious process recognized in concrete. Alkali Silica Reaction is a chemical reaction between reactive silica in aggregates and alkalis (Na_2O and K_2O) present in the cement paste. The above reaction absorbs water to form Alkali Silica gel which builds up pressure as it swells causing internal pressures in the concrete that eventually leads to cracks. The Alkali Silica gel varies considerably in composition depending upon the amount of Alkalis present in the cement and reactive Silica from the aggregates. Typical deleterious features of Alkali Silica reaction in concrete structures include cracking, expansion and consequence misalignments of structural elements, spalling of fragments at surface concrete as 'pop-outs'. The reaction typically takes 5 to 12 years to develop, though there are many exceptions and it is most severe where alkali concentrations in the concrete pore fluids are high. During 1920's and 1930's number of concrete structures in California, USA, were observed to develop severe cracking within the few years of construction although quite acceptable standards and quality control were maintained. In 1940 Stanton [1940] was able to demonstrate the existence of alkali-aggregate reaction as an intrinsic deleterious process between the constituents of concrete. During the following decade's research on alkali-aggregate reaction have been extensively carried out throughout the world.

2. Objective

The objective of the study was to investigate the change in resistivity of reactive chemicals causing the alkali silica reaction in concrete using the Electrochemical Impedance Spectroscopy.

3. Electrochemical Impedance Spectroscopy

The Electro Chemical Impedance Spectroscopy (EIS) is an electrochemical method used for measuring both Polarization resistance and uncompensated solution resistance accurately and instantaneously by applying an AC potential to an electrochemical cell that generates a small sinusoidal signal. The response to this potential is an AC current signal, containing the excitation frequency and its harmonics [Evgenij et al.2005]. This current signal can be analyzed as a sum of sinusoidal functions. The following expression is used to calculate the impedance of the system.

$$Z = R_m + \frac{2R_c}{1+\omega^2 R_c^2 C_c^2} - j\,\frac{2\omega R_c^2 C_c}{1+\omega^2 R_c^2 C_c^2} \qquad \text{---------- (1)}$$

4. Experiment

For this Experimental study aqueous solutions of 400 ppm sodium hydroxide (NaOH), 400 ppm calcium hydroxide ($Ca(OH)_2$), 200 ppm sodium silicate (Na_2SiO_3), water, and the mixture of all the above solutions were measured using Impedance Spectroscopy. The EIS measurements for the standard steel electrodes with an AC potential of 0.5 V were conducted over a frequency scan of 0.1 Hz to 1000 Hz. The impedance values are recorded at each frequency step, which is a sum of the polarization resistance at each electrode and the bulk resistance of the electrolyte. The Bode plots (Fig.1) were generated from which the polarization resistance and bulk resistance were obtained. In addition to the above study the conductance was also measured and verified to the bulk resistance (Fig.2). The relationship was linear.

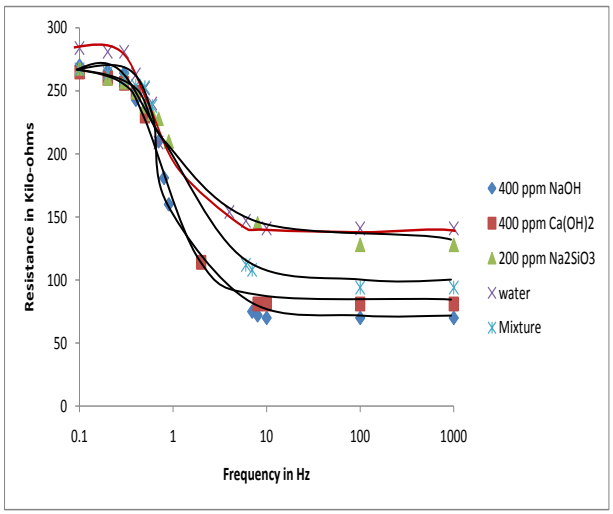

Fig.1 Bode Plot for different solutions using EIS

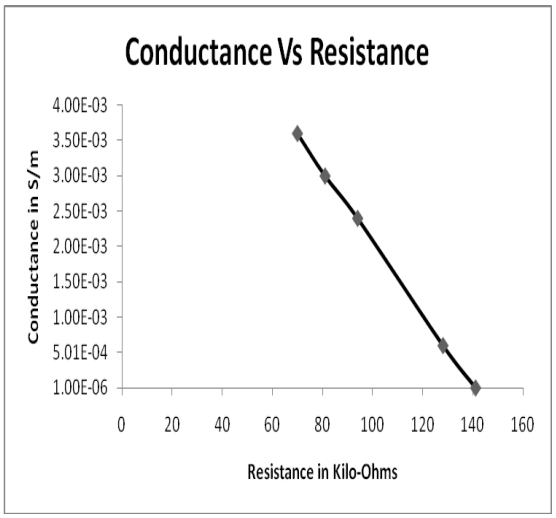

Fig.2 Conductance Vs Resistance Plot

5. Conclusions

Based on this study it is observed that EIS is a powerful tool in measuring the small concentrations of sodium, silica, calcium which are responsible for Alkali-Silica reaction in concrete. The bulk resistance was linearly selected to the conductance measured to obtain a relationship between conductance and bulk resistance (Fig.2).

6. Acknowledgement

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7. References

1. ASTM C 289-03 *"Standard Test Method for Potential Alkali Reactivity of Aggregates (Chemical Method)"*, Annual Book of ASTM Standards 2007, Vol 04.02.

2. Evgenij Barsoukov, Ross Macdonald, J. *"Impedance Spectroscopy Theory, Experiment, and Applications, Second edition,"* 2005 John Wiley &Sons.

3. Stanton, T. E., (1941) "*Influence of Cement and Aggregate on Concrete Expansion*," Engineering News -Record, February 1, pp. 59-61.

4. Stanton, T. E., (1940) *"Expansion of Concrete Through Reaction Between Cement and Aggregate,"* Transactions, American Society of Civil Engineers, Col. 107, pp. 54-126.