Impedance Spectroscopy Characterization of Smart Oil-well Cement Mixed with High Volume Fly Ash Class C

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Abstract
In this study, change in electrical resistivity of high volume fly ash mixed with smart oil well cement was investigated. Bulk resistance for specimens at different age of curing was obtained. By adding 50% fly ash class C to the oil well cement, resistivity increased 41%. Also, initial bulk resistivity for specimens with high volume fly ash was 1.56 Ω.m and increased to 69 Ω.m after 15 days.

1. Introduction

Impedance spectroscopy is a method of characterizing the electrical properties of materials and their interface with electronically conducting electrodes. (Campo, et al., 2002). Vipulanandan et al. (2013) used impedance spectroscopy to quantify the bulk and contact resistances of a piezoresistive structural polymer composite. Chen et al (2001) measured resistance of Portland cement with the two probe method with two copper plates; the frequency range was 0.01-100 kHz. According to Chen et al (2001) for all mixtures with different carbon fiber ratios, electrical resistance decreased by increasing the frequency and it reached a constant value after frequencies higher than 10 kHz.

2. Objective

The objective of this study was to use impedance spectroscopy in characterization of oil well cement modified with 50% fly ash class C.

3. Materials and testing method

All the materials were mixed at room temperature and cured at 170◦F. Cement Class H with 50 percentages of fly ash class C were added to the modified cement with 0.2% conductive additive. Water-to-cement ratio was 0.5. The two probe calibration factor. To represent the field condition, the specimens were cured in saturated sand, a new method developed recently.

4. Results

In current investigation, resistivity measurement for cement samples casted in standard mold was done for different age of curing. Resistivity reached a constant value after certain frequency. The Equivalent circuit that is shown in figures 1 represent electrical behavior of current smart cement. Comparison between experimental results and the model for specimens with high volume fly ash cured in high temperature and high humidity is shown in figure 2. Change in electrical bulk and contact resistivity during curing is shown in table 1. In two probe method contact resistivity is much higher than bulk resistivity due to polarization effect for DC measurement.

$$Z = R_b + \frac{2R_c(\sigma)}{1+\omega^2 {R_c}^2 {C_c}^2} - j\frac{2\omega {R_c}^2 C_c}{1+\omega^2 {R_c}^2 {C_c}^2} \quad (1)$$

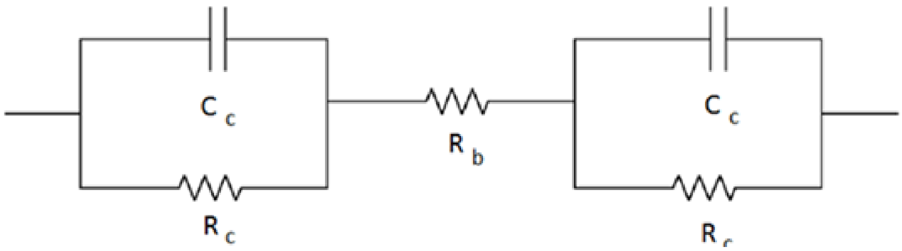

Figure 1: Equivalent circuit captured for piezoresistive material (Source: Vipulanandan et al. 2013)

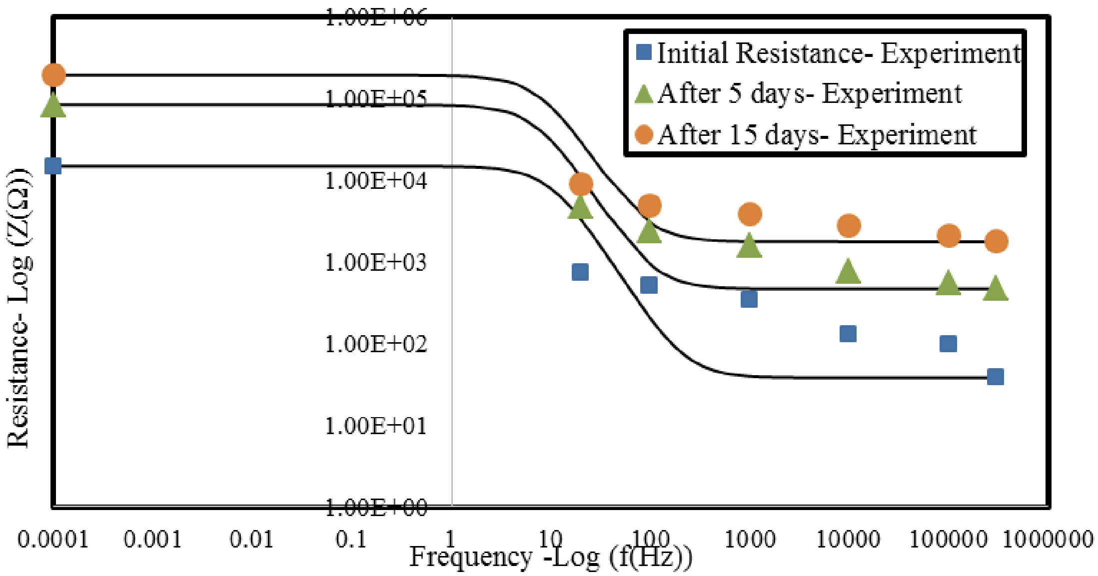

Figure 2: Impedance spectroscopy of smart cement and comparison with equivalent circuit

Table 1: Bulk and contact resistance of specimens with high volume fly ash class C

Age of curing	ρ_b (Ω.m)	ρ_c (Ω.m)
Initial	1.56	300
5 days	18.2	1648
15 days	69.42	3760

5. Conclusions

Based on experimental study, below conclusions are advanced:

1- Bulk resistance and contact resistance for different age of curing were obtained from the model.

2- The value for contact resistance was high as expected and both bulk and contact resistance was increased by increasing the age of specimens.

6. Acknowledgements

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