Electrical Characterization of Different Types of Modified Cements Using Impedance Spectroscopy

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Abstract: In this study, initial curing of various types of cements (Ordinary Portland Cement, Oil Well Cement and Ultra-Fine Cement) was investigated using the two probe method and Impedance Spectroscopy.

1. Introduction

Ordinary Portland Cement (OPC) is the most common type of cement used in construction of infrastructures, Oil Well Cement (OWC) is used to cement the oil well, and Ultra-Fine Cement (UFC) is commonly used as a repair material in oil well applications as well as infrastructure applications. The current study was done in order to characterize the piezoresistive cementitious materials electrically. It is important to monitor cementitious composites from the time of preparation through their curing period in order to characterize and understand their properties. Electrical characterization is one approach for cementitious composites having water and conductive fillers. Impedance spectroscopy (IS) is a powerful method for characterizing electrical properties. IS was used by Vipulanandan and Prashanth (2013) to characterize piezoresistive polyester polymer composite structural bulk sensor under various loading conditions. Also it has been reported that, based on IS measurements, bulk and contact resistances of materials can be calculated by representing the material with an equivalent electric circuit.

2. Objectives

Objective of this study was to characterize three different types of cementitious materials electrically using Impedance Spectroscopy.

3. Materials and Testing

Three types of cement were used in this study, namely OPC, OWC, and UFC. Water to Cement (w/c) ratio of 0.38 were used for OPC and OWC while a w/c ratio of 0.6 was used for UFC. Sodium Aluminum Silicate in the amount of 5% of cement weight was mixed with UFC. Carbon fiber (0.075% by weight of composite) was used to develop the piezoresistivity in all three materials. In order to characterize the electrical properties, 2x4" cylindrical specimens were prepared. Monitoring wires were embedded while preparing the specimen. In order to characterize the materials electrically, Impedance Spectroscopy measurements were taken between the wires for all the specimens just after preparing specimen and after 24 hours of curing by varying the frequency of the AC signal from 0.1 Hz to 300 kHz.

4. Results and Discussions

Equivalent circuits have been proposed in literature (Vipulanandan and Prashanth [2013]) to represent piezoresistive cementitious materials. In the most appropriate circuit, wires (contacts) are represented by a resistor and a capacitor in parallel, bulk material is represented by a resistor, and both contacts are connected to the bulk in series connection. From the resultant impedance of selected equivalent circuit, we could interpret that when frequency is very high, impedance due to contact becomes zero, hence bulk resistance of the material can be quantified and when the frequency of the applied signal is very low, the resulting impedance is equal to the bulk resistance plus contact resistance of both wires. Therefore, by performing impedance measurement through varying frequencies and adopting the equivalent circuit, material resistance can be quantified.

Figure 1 shows the impedance plots for OPC, OWC and UFC after preparing the specimen and after 24 hours of curing. The results agree with the equivalent circuit discussed above. Based on that, resistance and capacitance values were calculated and are presented in Table 1.

It was observed that bulk resistance increased with curing time while contact resistance decreased. For instance, for UFC, bulk resistance increased by 15 Ohms while contact resistance decreased by 6,495 Ohms within 24 hours. Contact resistance of OPC and UFC decreased with curing time while not much change was observed in contact resistance of OWC. Similar pattern was observed for contact capacitance as well.

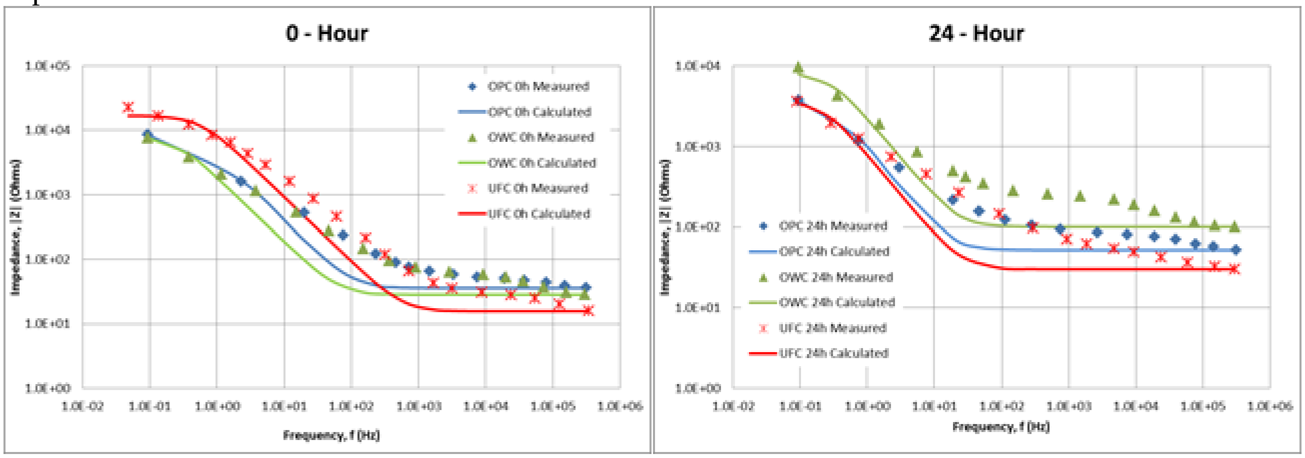

Figure 1: Comparison of Impedance after specimen preparation and after 24 hours of curing

Table 1: Resitivity, Resistance and Capacitance values after specimen preparation and after 24 hours of curing

	0 - Hour			24 - Hour		
	OPC	OWC	UFC	OPC	OWC	UFC
Bulk Resistance (Ohms)	36	28	15	52	101	30
Bulk Resistivity (Ohm meter)	0.682	0.827	0.632	1.05	2.71	1.26
Contact Resistance (Ohms)	4,329	4,107	8,423	1,969	4,139	1,928
Contact Capacitance (μF)	83	170	34	328	141	403

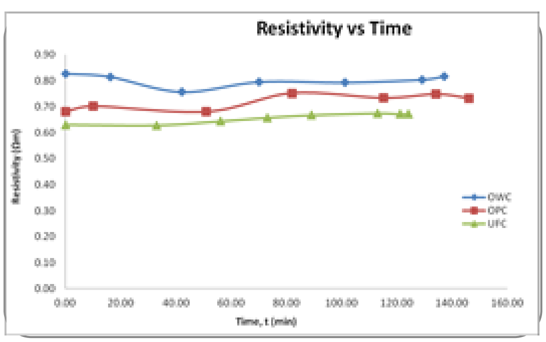

Figure 2: Comparison of Resistivity of Specimens

Figure 2 shows resistivity behavior of all three types of cements, from mixing through hardening when curing in the air for 2 hours. Based on the results, K factor ($R=K*\rho$; R-Resistance, ρ-Resistivity) was calculated and the resistivity, which is a material property, for all three types was compared at 24 hours. Oil well cement had the highest resistivity among the three materials.

5. Conclusions

All the cements are resistive materials. Oil well Cement had the largest change in resistivity in 24 hours.

6. Acknowledgement

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7. Reference

Vipulanandan, C. and Prashanth, P., (2013). "Impedance Spectroscopy Characterization of a Piezoresistive Structural Polymer Composite Bulk Sensor," Journal of Testing and Evaluation, Vol. 41, No. 6, pp. 898–904, doi:10.1520/JTE20120249. ISSN 0090-3973.