Change in Electrical Resistance of Modified Oil Well Cement with Silica Fume

M. Heidari[1] and C. Vipulanandan[1], Ph.D., P.E. and D. Richardson[2]
[1]Center for Innovative Grouting Materials and Technology (CIGMAT)
Department of Civil and Environmental Engineering
University of Houston, Houston, Texas 77204-4003
Email: mheidari@uh.edu, cvipulanandan@uh.edu Phone: (713) 743-4278
[2]Program Manger –RPSEA, Sugar Land, Texas 77478.

Abstract: Electrical resistance was monitored with from the initial curing to the hardened modified oil well cement. Experiments showed that electrical resistance can be used to characterize the curing cement. Addition of silica fume and modifying it with conductive fillers reduced the resistivity and stabilized the electrical resistance of the resistance compared to the unmodified cement. Relationships were found between the electrical resistivity and intrinsic behavior of material during the cement curing and compressive loading. The electrical resistivity changed during the curing of the cement and the hardened cement showed piezoresistivie behavior under compressive loading.

1. Introduction

With the growing interest for environmental concerns, monitoring the long-term durability of cement-based materials used in oil wells is of major importance to mitigate the risk of cement failures. Electrical resistivity is a good parameter to monitor the behavior of the cement. However, some modifications are needed since previous experiments showed that the electrical resistance of unmodified cement had so much fluctuation and was not interpretable. Silica fume is commonly used in oil well cement since it is tolerable in high temperature and increases the compressive strength of the cement (Muller et al. 1991).

2. Objective

The main objective of this study was to modify the cement with conductive fillers and use silica fume additive to increase the sensing ability of oil well cement in order to monitor the properties of the material from early hydration through various ages of curing by means of electrical resistivity. Also investigate the piezoresistive behavior of the modified cement.

3. Result and Analysis

Figure 1 shows the electrical resistivity response of the specimens modified with silica fume in different stages. The rate in change of electrical resistivity varies in different stages which illustrate a relationship between resistivity and cement hydration. A combination of conductive (mobile ions) and resistive products (solid hydration products) development in cement after mixing with water dominate these changes. In fig. 1(a) the decrease in resistivity is because mobile ions in cement (Na^+,K^+,OH^-,$SO4^{2-}$) solve in water and form a conductive electrolyte. Fig. 1(b) shows the resistivity is increasing with a higher rate which confirms the formation of hydration products which increase the porosity and the resistivity. Fig. 1(c) shows a decline in the rate of resistivity increase, which means the chemical reactions are slowing down, and in fig. 1(d) the resistance is stable and there is a slight change.

Figure 2 shows the fractional change in resistance for the specimen modified with silica fume upon compressive test. Note that before the compression test the resistance was constant and changes in resistivity illustrate the piezoresistivity response for the modified composite after 21 days. By increasing the compressive load the resistivity decreases till there is a crack or damage which increases the resistivity. Some cracks have been observed and shown in the curve. When the material fails the fractional change in resistivity significantly increases up to 20-100% in different specimens which shows the material is sensitive to major damages as well as small loads.

4. Conclusions

Compared to the unmodified cement, modifying oil well cement with silica fume increased the sensing ability of oil well cement by reducing and stabilizing the resistance.

(1) There is a correlation between the rate of changes in resistance in respect to time with cement hydration. Hence it is a good indicator of early age characteristics of cement.

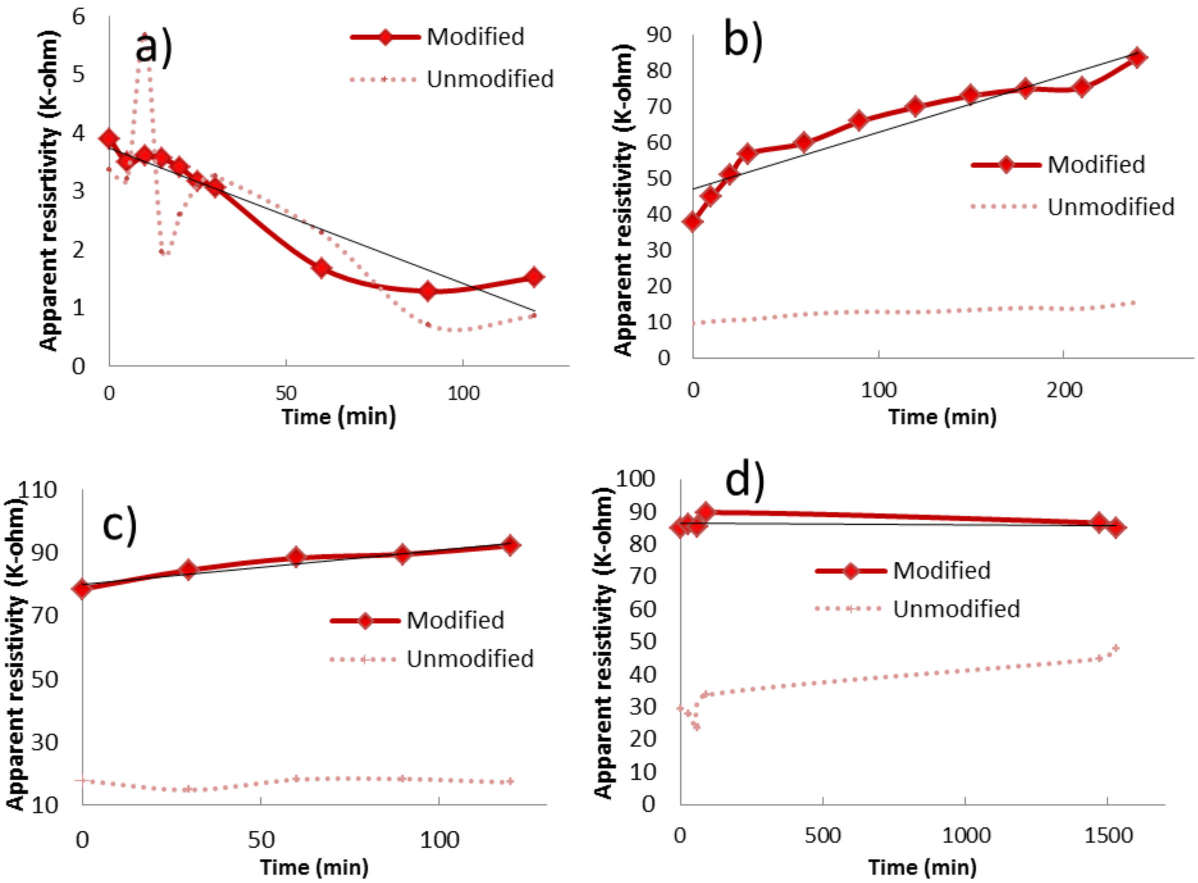

Figure 1. Apparent Electrical Resistivity of curing cement modified with silica fume a)After mixing b)After 1 Day c)After 3 days d)After 14 days

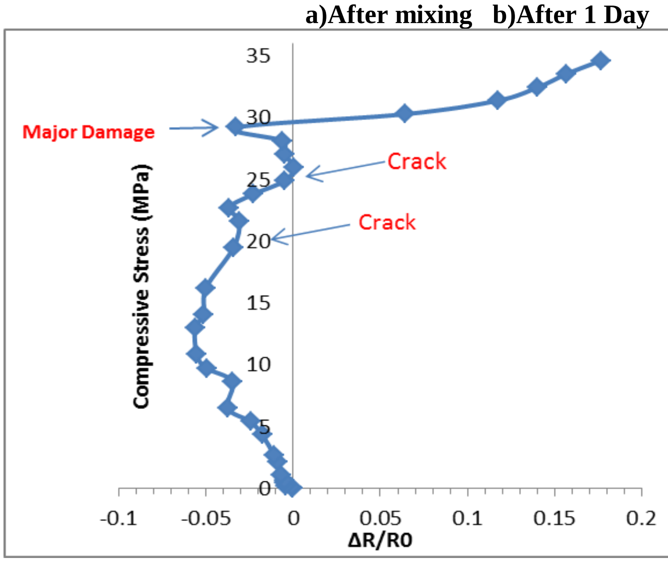

Figure 2. Piezoresistivity of modified cement with silica fume after 21 days

(2) The cement composites were sensitive to stress, crack and damage. Fractional change in resistivity (ΔR/R0) is a good parameter for monitoring the stress and damage.

5. Acknowledgement

This study was supported by CIGMAT with funding from DOE/NETL/RPSEA (Project 10121-4501-01).

6. References

Mueller D.T., Dillenbeck III R.L, “The Versatility of Silica Fume as an Oilwell Cement Admixture” Paper presented at 1991 SPE 21688 Production Operations Symposium Oklahoma City, Oklahoma, (April 7-9)