Electrical Resistance Variation with Curing Temperature for Modified Oil Well Cement

P. Kheiri[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
E-mail: pkheiri@uh.edu, cvipulanandan@uh.edu Phone: (713) 743-4278
[2]Program Manger –RPSEA, Sugar Land, Texas 77478

Abstract: In this study, changes in electrical resistance as a parameter to sense the curing of modified oil well cement with the addition of 10% silica fume was investigated. The testing was done at room temperature and 60^{o}C with and without water loss (with and without capping the mold) during the curing of the specimens. The time to reach the minimum resistance was affected by the curing temperature and curing condition. The ratio of change in the resistance (ΔR) to initial resistance (R_o) was about 4 times higher at 60^{o}C compared to the room temperature. Also the resistance ratio was sensitive to the open and closed condition during curing.

1. Introduction

The main factors that affect the rate of cement hydration are the water-to-cement ratio, curing condition, curing temperature, additives in the slurries. Also it must be noted that the conductivity process in aqueous solution due to ionic motion is different from that in metals. The conductivity invariably increases with increasing temperature, opposite to metals but similar to graphite. Hence at higher temperature, initial decrease of electrical resistance is more and faster because the heat excites electrons in the valence band of a ionic environment and gets them to move to the conduction band, freeing up spots for electricity to flow. As hydration starts in the cement, the ionic environment starts to disappear and electrical resistance will increase and this situation starts faster under higher temperature of curing. Hence it is important to develop methods to monitor the changes in the curing conditions in the cement.

2. Objective

The objective of this study was to determine the sensitivity of electrical resistance to the changes in the curing of cement at two temperatures with and without water loss.

3. Materials and Testing Method

All the materials were mixed at room temperature and cured at different temperatures with and without capping the mold. 10% of silica fume added to the modified oil well cement. The specimens were placed in molds and cured at different temperatures (Room temperature and 60^o C) and the electrical resistance was measured continuously up to 6 hours.

Table 1: Different Test Conditions

Specimen	Condition
1	Room temp(23^{o}C) with cap
2	Room temp(23^{o}C) without cap
3	In the oven(60^{o}C) with cap
4	In the oven(60^{o}C) without cap

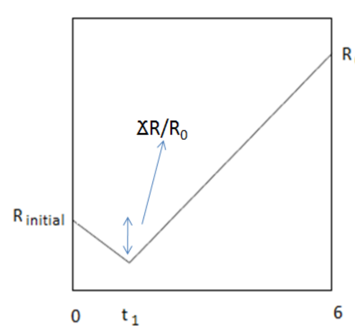

Figure 1:Typical Resistance-Time Relations

4. Results and Analysis

In all the specimens, the electrical resistance decreased and later increased sharply (Fig.1). The decrease in electrical resistance during the initial stage of curing is because of the increase of ionic concentration in the pore fluid. The most important ions that affect the electrical resistance at initial stage are Ca^{+2}, SO^{2-}, Na^{+} and K^{+}. Increase of electrical resistance during setting is due to the hydration of cement form calcium silicate hydrates and decrease in ions that are solved in water. It was observed that specimens at higher temperature hardened after about 3 hours, compared to specimens at room temperature which hardened after 5 hours. Fig.2 the time taken to reach the minimum resistance are compared. The specimens cured at room temperature required more than double the time to research the minimum resistance than the specimens cured at 60°C. Capping the specimen showed greater effect at room condition compared to 60°C to reach the minimum resistance. Figure 3 shows the changes in relative electrical resistivity ratio ($\Delta R/R_o$) after 6 hours. The change in resistivity ratio was about four times higher at 60°C curing specimen compared to the room temperature curing specimens. Hence the electrical resistivity was sensitive to the changes in the curing temperature of the modified oil well cement.

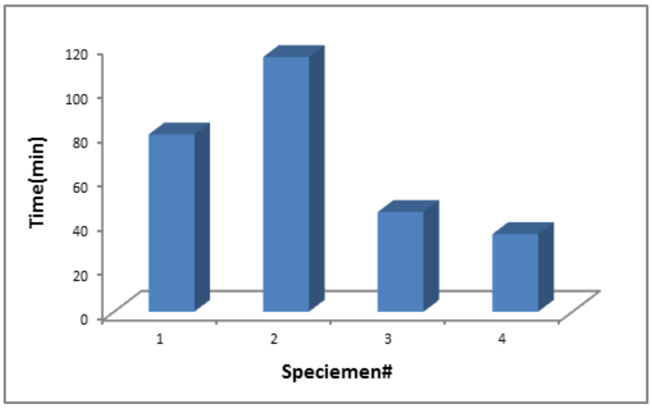

Figure 2. Time to Research Minimum Resistance for Different Conditions

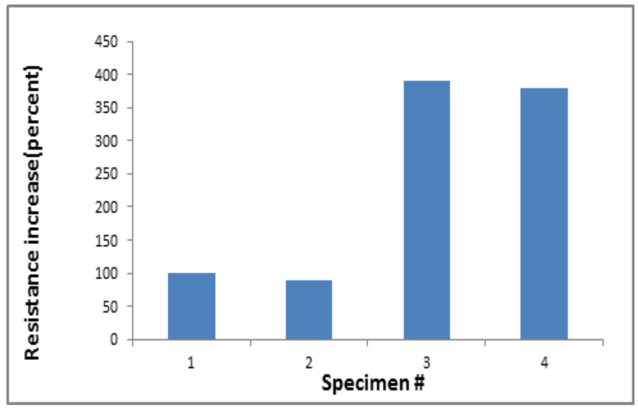

Figure 3. Change In Electrical Resistance Ratio After 6 Hours

5. Conclusions

Based on the experimental study of modified oil well cement curing at two different temperatures following conclusions are advanced:

1) The time to reach the minimum resistance (resistivity) depended on the curing condition and water loss (open versus closed (capped mold)). The time to reach the minimum resistance for the room temperature cured specimens were more than double compared to the cement cured at 60°C.
2) The electrical resistivity ratio for 60°C cured specimens was 4 times higher than the room temperature cured cement.
3) Hence electrical resistivity is a good indicator of the curing temperature of the cement.

6. Acknowledgements

This study was supported by the Center for Innovative Grouting Materials and Technology (CIGMAT) with funding from DOE/NETL/RPSEA Project (10121-4501-01).