# Effect of High-volume Fly Ash on Oilwell Cement Curing and Piezoresistive Behavior

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**Abstract:** In this study, resistivity change during curing and compressive loading was studied. Oil-well cement class H and fly ash class C was used in this investigation. Initial resistivty for specimen contained cement was 1.1 Ω.m compared to 1.55 Ω.m for the specimens with high percentage fly ash (Class C). Resistance change during compression for specimens with high percentage of fly ash was 300% which was about twice of without fly ash.

**1. Introduction:** Fly ash-cement concrete has been utilized in buildings and infrastructure systems for many years as it is useful for modifying systems for many years such as workability, strength, shrinkage and heat evolution.(Termkhajornkit 2006). Some studies showed fly ash can be used in oil-well operation for plugging purposes. According to Cho(2002) Class C fly ash can be retarded like cement when slurried and it can be pumped and placed like cement with coiled tubing instead of employing a rig. Use of fly ash, leads to provide a cheaper, environmentally friendly, and more economical method of plugging wells(Cho et al. 2002). Also pozzolans such as fly ash and silica fume are very effective in reducing the apparent diffusion coefficient for chloride at a given water to cement ratio (Aldykiewicz et al. 2005) According to the literature, evaluation of fly ash pozzolanic activity can be carried out by conductivity measurement of natural pozzolanic materials in different aqueous media. The reaction between calcium hydroxide in aqueous solution and pozzolanic material as finely divided powder produces a decrease in electrical conductivity of the suspension (Luxan 1989).

**2. Objectives:** Overall objective was to investigate the effect of fly ash on electrical resistivity during curing. Specific objectives were as follows: 1. characterizing the curing properties of cement with and without high volume Fly ash and 2. Effect of Fly ash on piezoresistive behavior of smart cement.

**3. Methods and materials:** Three different samples were made and cured at room temperature. Cement Class H with Different percentages of fly ash class C (0, 50%, 100%) were added to the modified cement with 0.1% conductive additive. Water-to-cement ratio was 0.5 and Silica fume was added to reduce the free water. The two probe calibration factor, k($R=\rho k$), was determined for the specimens. AC current with different frequencies were used to measure electrical resistance and capacitance was measured for 1 month. These results were for two wires placed at a vertical distance of 2 inches. After 1 month the specimens were demolded and electrical resistance change during compressive load was investigated.

**4. Results and discussions:** By adding certain amount of conductive additive and measuring the electrical resistance, type of material could be sensed. Fig.1 shows different materials have different electrical resistivity during initial setting after mixing. The resistivity with fly ash was higher than the pure cement. As shown in Fig. 1, for cement, electrical resistance decreased at initial stage of hydration and then as the hydration started, it increased. This phenomenon was seen with mix with fly ash but at a slower rate.

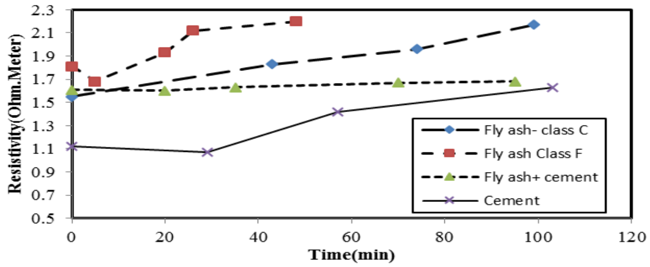


**Figure 3: Resistivity change during initial setting**

To characterize the curing properties of different specimens, resistivity change after 2 hours ($RI_2$), 24 hours ($RI_{24}$) and 11 days ($RI_{11d}$) and also weight change after 11 days ($RI_{11}$) were measured. Hydration for specimens contained cement was faster than specimens with high percentage of fly ash. $RI_{11d}$ for specimens contained cement was about 1000% compare to 278% for specimens with high percentage of fly ash. For specimens with high percentage of fly ash, increase in electrical resistance started after about 8 days. Adding fly to the solution ash, holds the water inside the solution and ions that are solved in water remained in solution for longer time. In other words adding fly ash retards the hydration and this fact was sensed by electrical resistivity change.

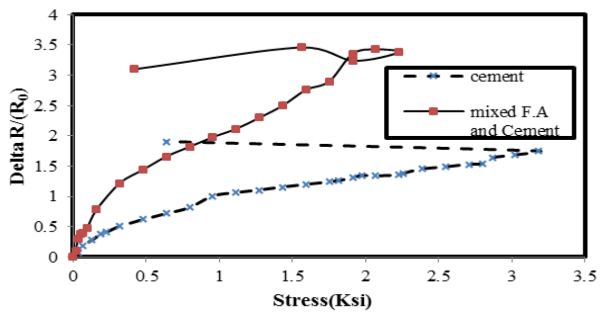


**Figure 2. Resistance change during compression test on smart cement (After 20 days)**

By adding fly ash to the slurry weight change during curing was reduced. By adding 50 percent fly ash class C weight change reduced by about 25% and for specimens contained 100% fly ash it reduced up to 75%. Cement with and without fly ash additive were piezoresitive. For specimens with higher percentage of fly ash resistance change up to failure was about two times of specimens contained cement.

**5. Conclusions:** The resistivity for mixed fly ash-cement is higher than(1.6 vs 1.2) cement slurry without fly ash**. 2.** During the initial curing resistance decreased to a minimum within first 70 minutes and then as hydration started, it increased sharply. **3.** By adding fly ash, slurry became more sensitive to the compressive stress and fractional change of electrical resistance during compression increased. **4.** By comparing $RI_{24}$ and $RI_{11d}$ for different specimens material properties could be captured. $RI_{11d}$ for specimens contained cement was about 1000% compared to 278% for specimens with high percentage of fly ash.

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