Effect of Silica Fume on the Fluid Loss and Piezoresistive Properties of Smart Oil Well Cement

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Abstracts: The effect of silica fume (SF) on the fluid loss, electrical resistivity during curing and piezoresistive properties of smart oil well cement slurry was investigated. SF of up to 5% was added to the smart cement slurry and SF increased the initial resistivity but decreased the resistivity with curing time. Adding SF reduced the compressive strength after 7 and 28 days of curing. The piezoresistive response after 7 days was 250% and remained the same after 28 days. Addition of SF reduced the fluid loss of smart cement.

1. Introduction:
Silica fume or microsilica is ultrafine non-crystalline silica which is a byproduct of the manufacture of elemental silicon and ferrosilicon alloys (Dauo and Piot, 2009) is used as pozzolanic material. Due to its high surface area (50 times that of cement) SF is used in light-weight cement slurry as it allows cement to absorb high amount of water and provide low permeability (Dillenbeck et al. 1990, Dauo and Piot, 2009). Due to its wide use in oil well cement slurry, SF can be tested with the smart cement slurry that has been developed by Vipulanandan et al., 2014 with class H cement and 0.075% of conductive filler (CF) which has a sensing ability in terms of electrical resistivity and piezoresistivity.

2. Objectives:
Investigate the effect of SF on the fluid loss, electrical resistivity and piezoresistivity of smart oil well cement slurry.

3. Materials and Methods:
Smart cement was prepared by mixing commercially available class H oil well cement and 0.075 % carbon fiber. The water cement ratio used was = 0.4. Various amounts of SF (0%, 2%, and 5%) were used to make the cement slurry. The SF was first mixed with cement and then water and carbon fiber was added to the mix. To determine the electrical resistivity, two probe method with fixed 2 electrical wires were used to measure the resistance. The resistivity (ρ) is defined as RA/L (where, R = measured resistance, A = area of the electrical flow, L = distance between the probe). The two probe test mold was first calibrated by determining the resistivity of the cement slurry with a direct resistivity measuring device and the corresponding resistance measurement by an AC resistance measuring device. Then from the resistivity relationship, the A/L ratio of the test mold was determined. This ratio was used to determine the resistivity of hardened cement.

4. Results and Discussion:

4.1 Fluid loss: Fluid loss test was done in an API HPHT fluid loss test cell under 100 psi pressure up to 30 min. With 5% SF, the fluid loss at 30 min was determined as 124 mL which was 143 mL for smart cement only, a 13% fluid loss reduction with addition of 5% Silica Fume (Figure 1).

4.2 Resistivity: The effect of Silica Fume (SF) on the resistivity of the smart oil well cement slurry with curing time up to 28 days was determined and compared with that of smart cement only. The results showed that the initial resistivity (1.24 Ω-m) was increased by about 25% with addition of 5% SF and the resistivity after 24 hours of curing (1.75 Ω-m) was decreased by about 20% (Fig. 1). The minimum resistivity was 1.07 Ω-m and the time to reach minimum resistivity was reduced to 80 min which was about 180 min for smart cement only. But with curing time, the resistivity increase was lower than that of the smart cement only.

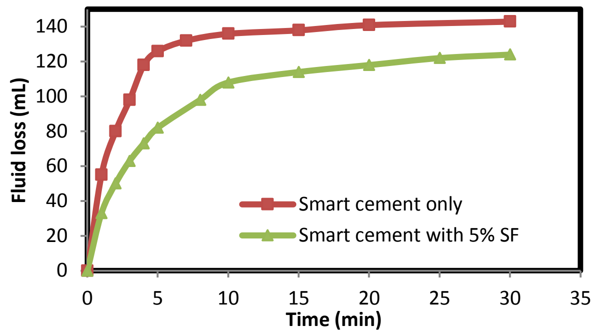

Figure 1. Fluid loss test of smart cement slurry with and without SF

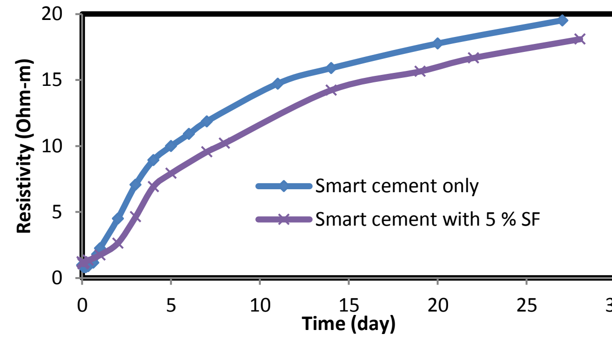

Figure 2. Resistivity with curing time of smart cement slurry with and without SF

4.3 Compressive Strength and Piezoresistive Properties: Addition of 5% SF reduced the compressive strength of smart cement by 26% and 24% after 7 days and 28 days of curing respectively. The piezoresistive response showed different trend. Addition of 5% SF reduced the piezoresistivity by 54% than that of smart cement after 7 days (Fig. 3). But after 28 days of curing, the piezoresistivity with addition of 5% SF was almost same to that of smart cement (Fig. 4).

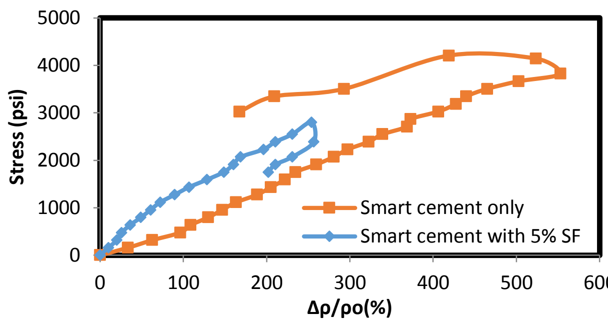

Figure 3. Compressive stress Vs piezoresistivity of smart cement slurry with and without SF at 7 day

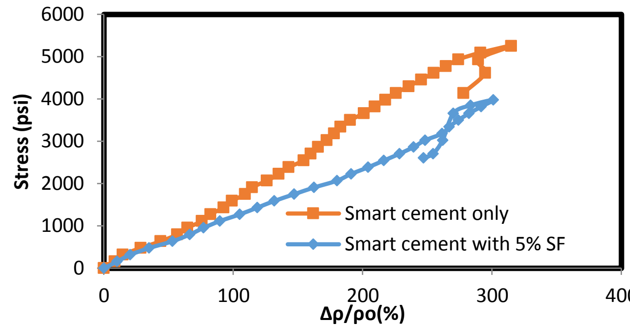

Figure 4. Compressive stress Vs piezoresistivity of smart cement slurry with and without SF at 28 day

5. Conclusions: 1. SF decreased the fluid loss of the smart cement slurry. The addition of 5% SF decreased the 30 min fluid loss by 13%.

2. SF increased the initial resistivity but decreased the resistivity with curing time. Addition of 5% SF increased the initial resistivity by 25%, but decreased the 24 hour resistivity by 20%. After 28 days of curing, the resistivity of the cement with 5% SF was 8% less than that of smart cement.

3. Addition of 5% SF reduced the compressive strength of smart cement by 26% and 24% after 7 days and 28 days of curing respectively. The piezoresistivity of the cement with 5% SF was decreased by 54% from that of smart cement after 7 days of curing but was unchanged after 28 days of curing.

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7. References:
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