Effect of Acrylamide Polymer on Shrinkage, Strength and Piezoresistivity of Smart Cement

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Abstract
The purposes of this study were to evaluate flexural strength, piezoresistivity and volume shrinkage of Smart cement with applying acrylamide polymer. Effect of acrylamide addition to smart cement was investigated at closed room condition. Based on literature review 10% (AV100) acrylamide solution was added to the smart cement and the change in electrical resistivity, length and weight were measured during the curing of the cement. Addition of acrylamide changed the typical electrical resistivity trend during the curing of the cement and also reduced the Moisture loss and shrinkage. Piezoresistivity at failure for Smart Cement control specimen and with polymer addition were 60% and 40% respectively. Flexural strength of smart cement was significantly reduced with addition of acrylamide.

1. Introduction

The consequences of cement shrinkage are non-trivial: in North America, there are literally tens of thousands of abandoned, inactive, or active oil and gas wells, including gas storage wells, that currently leak gas to surface (Dusseault, et al., 2000). The conditions for gas migration develop when the hydrostatic pressure of the hydrating cement slurry column slowly declines and finally falls below the pore pressure of a gas bearing formation. This pressure decline is mainly caused by chemical shrinkage of the cement. A low chemical shrinkage will reduce the pressure decline and hence the risk of gas migration (Skalle, et al., 1997). Hence there is a requirement for studying moisture losses, shrinkage, strength and piezoresistivity of oil well cement. The polymer latex admixture is commonly used to improve the flexural strength, workability, and toughness of glass fiber reinforced concrete (Wang, et al., 2005). shrinkage strains of glass fiber reinforced concrete were found to decrease with increases in the SBR polymer content (Ianleng & Leelawat, 2017). Because of these properties of polymer, the laboratory testing program was designed by adding the acrylamide polymer into cement to achieve the less shrinkage.

2. Objective

The objective of this study was to investigate the effect of acrylamide polymer addition on the oil well cement's shrinkage, strength and piezoresistive behavior.

3. Materials and Methods

In order to quantify the amount of Shrinkage and moisture loss in Smart cement, two specimens were casted with polymer solution-to-cement ratio of 0.38 and the polymer solutions was prepared with 10% monomer(AV100) addition and one control mix which was prepared without addition of polymer with the water-to-cement ration of 0.38. Conductive filler of 0.03% by total weight was used and dispersed into the dry binder. Then the dry binder was mixed with water in a jar by using a drill pit mixer. Initial conductivity measurements were taken by using conductivity probe and the readings were converted to resistivity. Cylindrical (2" x 4") specimens were prepared and tested under uniaxial compression and splitting tensile test was done after 10 days. Specimens were oven heated just before the test to eliminate the effect of moisture. Resistance measurements were taken by using LCR meter. To minimize the contact resistances, the resistance was measured at 300 kHz using two-probe method. Since the sample has four probes, six combinations of readings were taken and averaged to get more accurate results.

4. Results and Discussion

Figure 1 shows the resistivity behavior of smart cement and polymer modified smart cement from mixing through hardening to curing in the air for 10days. Polymer addition in the cement has removed the dip in resistivity. It has proven that the resistivity is a better tool to monitor the foreign particle addition in the cement. Initial resistivity of control specimens is lesser compare to the polymer modified specimen. The acrylamide polymerization is an exothermic reaction and it influenced in the initial rapid resistivity increase. After one day the resistivity change was reduced compare to the control smart cement specimen. It's an evidence of less hydration which leads to lower strength.

As shown in the Figure 2 the strain tolerance of the polymer modified smart cement was increased by 25 times of the control smart cement. In the other hand the piezoresistivity was reduced from 60 to 40% because of the addition of polymer (Figure 3). Piezo-resistivity and splitting tensile strength of the control smart cement specimen were 60 % and 750 psi and the polymer modified specimen are 40 % and 300 psi. Addition of acrylamide polymer reduced a significant amount of strength of smart cement. It can be seen the initial resistivity values are indirectly proportional to the ultimate tensile strength.

Figure 5 compares the percentage volume shrinkage of acrylamide modified smart cement with curing time. As seen in figure, it is obvious that the shrinkage was reduced from 6.0 to 0.3 % by adding 10% of acrylamide. Both specimens prepared with acrylamide addition were showed the similar shrinkage values. Observed that the major change in the shrinkage was happened in one day its mainly because of the bleeding then it remained same. Polymer addition might have blocked the bleeding in cement slurry.

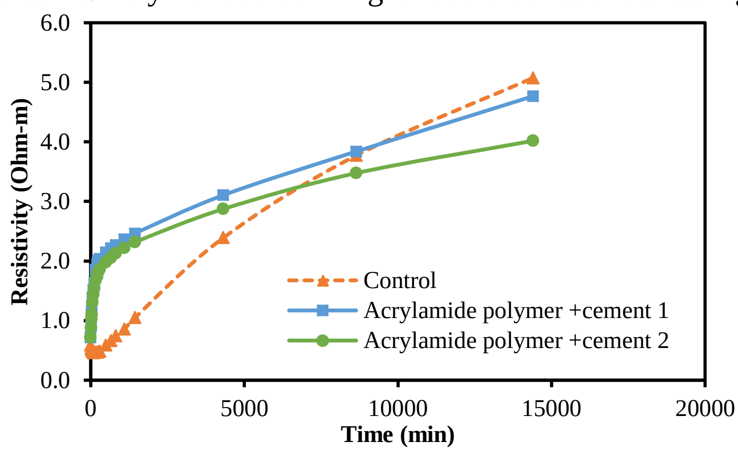

Figure 1: Electrical resistivity during curing time

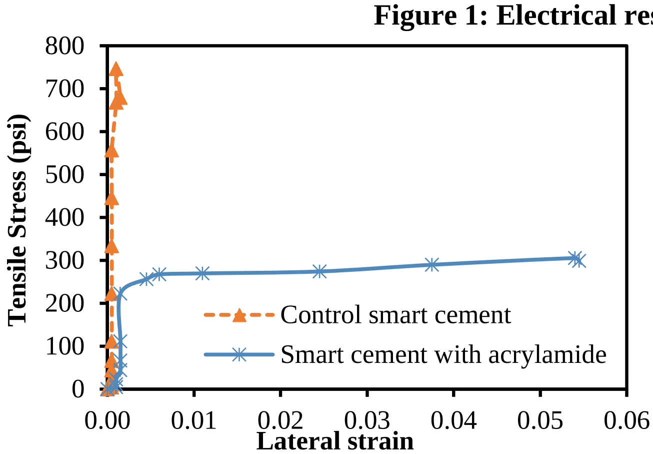

Figure 2: Splitting tensile test of the smart cement and polymer modified smart cement

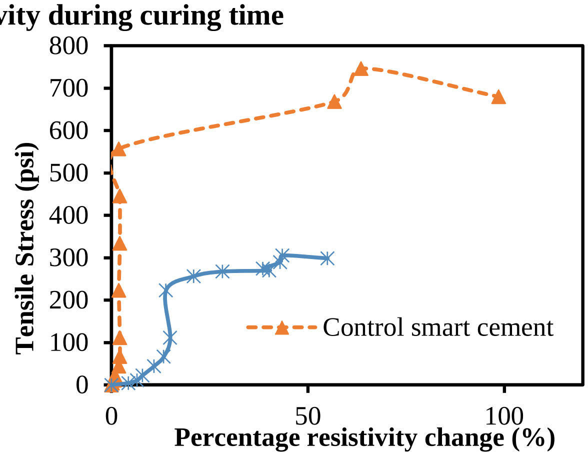

Figure 3: Piezoresistive behavior of the smart cement and polymer modified smart cement.

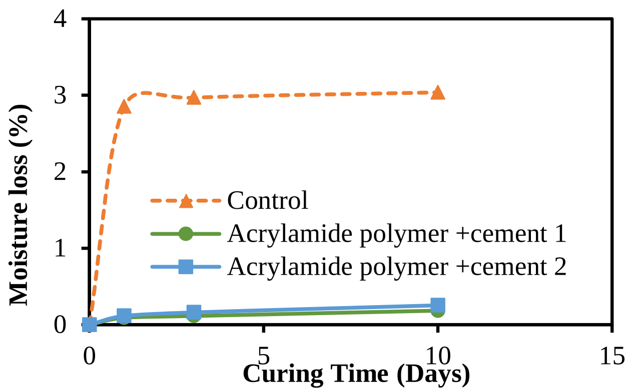

Figure 4: Moisture loss of polymer modified smart cement with curing time

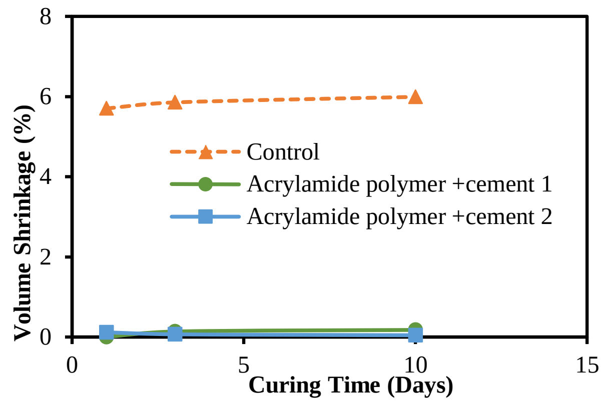

Figure 5: Volume shrinkage of polymer modified smart cement with curing time

4. Conclusions

1. Resistivity monitoring was used as the tool to characterize the acrylamide addition.
2. Average piezoresistivity of smart cement and acrylamide modified smart cement were 60% and 40% at ultimate tensile strength.
3. Resistivity change was negative for the acrylamide replacement while loading.
4. Acrylamide addition into the oil well cement slurry reduced the volume shrinkage and moisture loss from 6% to 0.3% from 3% to 0.1% respectively.
5. Flexural strength was decreased to half with addition of acrylamide polymer.

5. Acknowledgment

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6. References

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