Behavior of Hydrophilic Polyurethane Resin Modified Smart Cement

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Abstract: The effect of adding different percentages of Hydrophilic Polyurethane Resin (HPR) on the smart cement behavior was investigated. The ultimate piezoresisitivity of 1and 2 percentages of HPR modified smart cement increased by 3% and 2% from 375% for smart cement to 385% and 381% respectively. 5% and 10% HPR modified smart cement showed reduction of 75% and 49% in ultimate piezoresitivity from 375% to 94% and 193% respectively.

1. Introduction

Proper cementing is critical to ensure the integrity of the wellbore during the installation and entire service life. In order to characterize the different properties of the cement, several test procedures have been suggested by API including slurry density, fluid loss, rheological, thickening time, permeability and compressive strength test. Vipulanandan et al. (2014) suggested electrical resistivity measurements as a simple, nondestructive method for monitoring the zonal isolation throughout the whole cementing procedure and also the long-term characterization of oil well cement. They also studied the piezoresistive behavior of modified cementitious and polymer composites which is defined as the changes in the electrical resistivity of the materials with applied stress.

2. Objective

The overall objective of this study was to investigate the effectiveness of up to 10% HPR additive on the behavior of the smart cement.

3. Materials and Methods

The test specimens were prepared following the API standards. API class H cement was used with water-cement ratio of 0.38. For all the samples 0.03% (By the weight of total, BWOT) of conductive filler (CF) was added to the slurry in order to enhance the piezoresistivity of the cement and to make it more sensing. The smart cement slurry was mixed with different percentage of 1, 2, 5 and 10% of HPR. After mixing, the slurries were casted into the cylindrical molds with height of 4 inches and diameter of 2 inches, in which, two conductive wires were embedded 2 inches far from each other in order to monitor the resistivity development of the specimens during the curing time and also to measure the piezoresistivity of the specimens.

4. Result and Discussion

The compressive strength of the cement was 1.84 ksi after1 day of curing. Adding 1% of HPR to smart cement reduced the compressive strength by 7% to 1.72 ksi; however addition of 2% HPR to smart cement leaded to 58% increment in compressive strength to 2.9 ksi which is due to polymer formation in smart cement. Smart cement modified by 5% HPR had the lowest compressive strength of 0.076 ksi, 96% reduction. Addition of 10% of HPR made the slurry set 5 minutes after mixing and the compressive strength reduced by 63% to 0.69 ksi. As shown in Fig.1, after 1 day of curing, the piezoresistivity of the smart cement was 375%. Parameters p and q for the model were 0.68 and 0.61 respectively. The ultimate piezoresisitivity of 1and 2 percentages of HPR modified smart cement were 385% and 381% respectively, 3% and 2% increment. 5% and 10% HPR modified smart cement showed ultimate piezoresitivity of 94% and 193% respectively, 75% and 49% reduction. The transition of HPR formation from polymer to foam also affected the piezoresistivity behavior of the smart cement. As shown in Table 1, the model parameters of the p-q model for the modified cement with 1% of HPR are 0.62 and 0.55, with 2% are 0.54 and 0.49, with 5% are

0.10 and 0.75 and with 10% are 0.28 and 0.41 for p and q respectively.

In order to represent the piezoresistive behavior of the hardened cement, p-q model was used in which, σ_{max} is the maximum stress, $(\Delta\rho/\rho)_0$ is the piezoresistivity of the hardened cement under the maximum stress and p and q are experimentally fit parameters. As shown in Eqn. (1), in deep well it will be easy to estimate the stress on the cement by measuring the changes in the resistivity of the smart harden cement.

$$\sigma = \frac{\sigma_{max}\times\left(\frac{\left(\frac{\Delta\rho}{\rho}\right)}{\left(\frac{\Delta\rho}{\rho}\right)_0}\right)}{q+(1-p-q)\times\left(\frac{\left(\frac{\Delta\rho}{\rho}\right)}{\left(\frac{\Delta\rho}{\rho}\right)_0}\right)+p\times\left(\frac{\left(\frac{\Delta\rho}{\rho}\right)}{\left(\frac{\Delta\rho}{\rho}\right)_0}\right)^{\left(\frac{p+q}{p}\right)}} \tag{1}$$

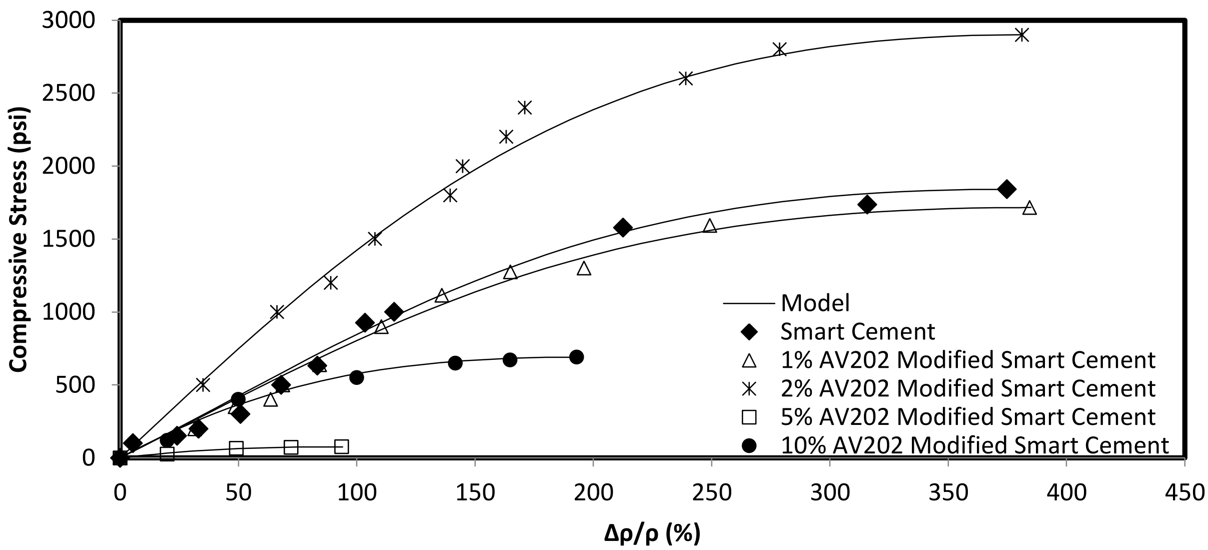

Figure 1: Piezoresistive behavior of the smart cement with and without HPR modification after 1 day of curing

Table 1: Model parameters of p-q model for evaluating the piezoresistive behavior, Compressive Strength and Ultimate Piezoresistivity of the HPR modified smart after 1 day of curing

Cement	***1 Day Curing***			***Compressive Strength (psi)***	***Ultimate Piezoresistivity (%)***
	$p_{1\,Day}$	$q_{1\,Day}$	R^2		
Smart Cement	0.68	0.61	0.99	1840	375
1% HPR Modified Smart Cement	0.62	0.55	0.99	1720	385
2% HPR Modified Smart Cement	0.54	0.49	0.99	2900	381
5% HPR Modified Smart Cement	0.43	0.44	0.99	76	94
10% HPR Modified Smart Cement	0.28	0.41	0.99	690	193

6. Acknowledgements

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7. References

1. Vipulanandan, C., Krishnamoorti, R., Saravanan, R., Qu, Q. and Narvaez, G. (2014). "Development and Characterization of Smart Cement for Real Time Monitoring of Ultra-Deepwater Oil Well Cementing Applications." OTC 25099-MS, pp. 1-12.