Effect of Foam on the Piezoresistive Properties of Smart Cement in Slurry and Hardened State

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Abstract: In this study, the effect of foam on the peizoresistive properties of smart cement slurry and hardened cement cured for 28 days were investigated. The results of the peizoresisitive properties for cement samples with different foam content are presented. Foam content was varied up to 20% are investigated. With the addition of 20% foam, the resistivity change at 600 psi (4 MPa) compressive stress increased from 8% for the smart cement slurry with no foam to 22% with 20% foam, about 175% increase in the piezoresistivity. The compressive strength of smart cement was reduced to 220 psi from 1300 psi, an 83% reduction and the peizoresistivity reduced from 350% to 110% with the addition of the foam for one day but the change in piezoresistivity per applied stress increased from 0.27%/psi to 0.5%/psi. Similarly for 28 days the change in peizoresistivity per applied stress increased from 0.09%/psi to 0.13%/psi and the strength increased to 2800 psi and 760 psi for smart cement without and with 20% foam respectively.

1. Introduction

Foam cement is a light weight and thermal insulating material consisting of cement matrix with porous structure created by injecting preformed foam into the cement slurry during the mixing process [1]. Foam cement is defined as a cementitious material having minimum of 20 percent by volume of foam in the slurry in which air pores are entrapped. But foam cement also present some disadvantages such as low ductility, low strength especially flexural strength. As deep-water exploration and production of oil and gas expands around the world, there are unique challenges in well construction beginning at the seafloor. Also preventing the loss of fluids to the formations and proper well cementing have become critical issues in well construction to ensure wellbore integrity because of varying downhole conditions [2]. Moreover the environmental friendliness of the cements is a critical issue that is becoming increasingly important. Lack of cement returns may compromise the casing support and excess cement returns cause problems with flow and control lines [2]. Hence there is a need for monitoring the cementing operation in real time. At present there is no technology available to monitor the cementing operation real time from the time of placement through the entire service life of the borehole. Also there is no reliable method to determine the length of the competent cement supporting the casing. Foam cement systems much lighter than water, yet without compromising essential mechanical properties to establish life-of-the-well zonal isolation has been reported.

2. Objective The overall objective was to quantify the effect of foam content on the piezoresistive behaviour of smart oil well cement in slurry and hardened state.

3. Experiment

3.1 Raw Materials

Oil well cement of Class H was used for the formulation of the foam cement. A water to cement ratio of 0.38 was employed. Conductive Fillers of about 0.04% of weight of cement were added for the mix to enhance the sensing properties. Preformed foam was used in percentage of total weight of the slurry.

3.2 Methods

API Fluid Press method was used for measuring the peizoresistivity of the slurry. Hydraulic Compression testing machine was used for monitoring the piezoresistive behavior for up to 28 days.

4. Results and Discussion

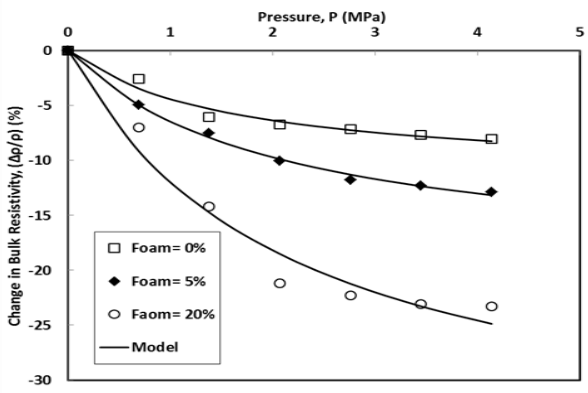

Figure 6. Peizoresistivity of smart cement slurry with and without foam

The resistivity of the smart cement slurry decreased nonlinearly with increase in the pressure (Fig. 1). At 600 psi (4 MPa) pressure the decrease in resistivity was 8%, indicating the piezoresistivity characteristics of the smart cement slurry. The decrease in resistivity was 12% for 5% foam showing that the piezoresistivity characteristics of the smart foam cement slurry increased by 50%. The decrease in resistivity was 22%, for 20% foam showing that the piezoresistivity characteristics of the smart foam cement slurry increased by 175%, making the smart foam cement to be more sensing.

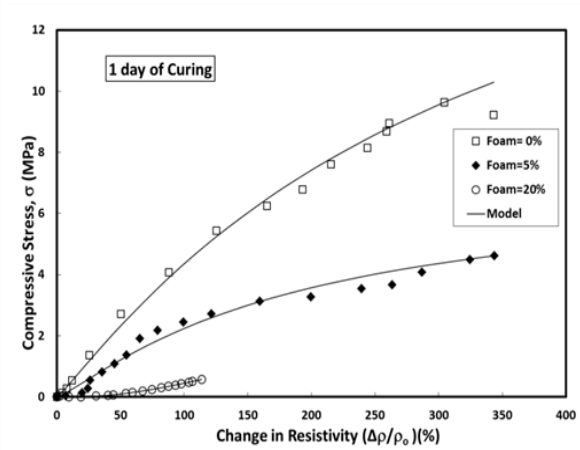

Figure 7. Peizoresistivity of smart cement with and without foam for one day curing

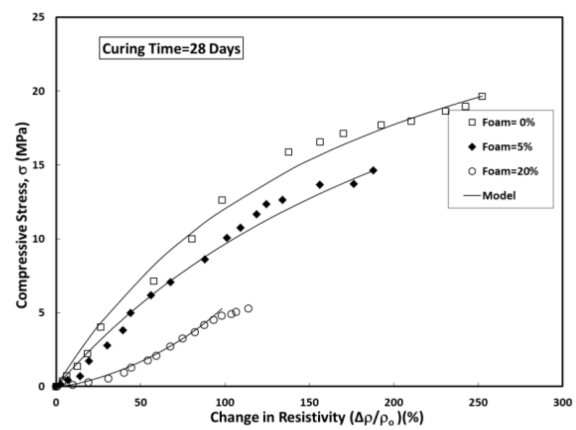

Figure 8. Peizoresistivity of smart cement with and without foam for 28 days curing

The average percentage change in resistance at peak compressive stress of 1300psi of the smart cement after 1 day of curing was 343% and was 250 % after 28 days for a peak stress of 2800 psi. (Fig. 2& 3) The average percentage change in resistance at peak compressive stress of 650 psi for the smart cement with 5% foam after 1 day of curing was 304%, an 11% reduction compared to the smart cement without any foam. For 28 days the average percentage change in resistance at a peak stress of 2100 psi was 188%. The average percentage change in resistance at peak compressive stress of 220 psi for the smart cement with 20% foam after 1 day of curing was 113%, a 67% reduction compared to the smart cement without any foam. For 28 days curing, the average change in resistance at peak stress of 760 psi was found to be 100% for smart cement with 20% foam.

5. Conclusion: The resistivity change was increased by 175% in smart cement slurry with the addition of 20% foam. The peizoresistivity (%)/psi increased from 0.27%/psi to 0.5%/psi for one day curing and similarly for 28 days the peizoresistivity (%)/psi increased from 0.09%/psi to 0.13%/psi with addition of 20% foam.

6. Acknowledgements: This study was supported by the Center for Innovative Grouting Materials and Technology (CIGMAT) and Texas Hurricane Center for Innovative Technology (THC-IT), University of Houston, Houston with funding from DOE/NETL/RPSEA (Project 10121-4501-01).

7. References: 1. Akthar F. K. and Evans J. R. G., (2010), “High Porosity (>90%) Cementitious Foams.” Cement and Concrete Research, 40(2): 352-358. 2. Ravi, K. et al. (2007), "Comparative Study of mechanical Properties of Density-reduced Cement Compositions, SPE Drilling & Completion, Vol. 22, No. 2, pp. 119-126.