Effect of CO_2 Contamination during Initial Mixing on the Short-Term Behavior of Smart Cement

N. Amani and C. Vipulanandan, Ph.D., P.E.
Texas Hurricane Center for Innovative Technology (THC-IT)
Department of Civil and Environmental Engineering
University of Houston, Houston, Texas 77204-4003
E-mail: newsha.amani@gmail.com, cvipulanandan@uh.edu Phone: (713) 743-4278

Abstract: The effect of different CO_2 concentrations of 0.1%, 1% and 3% based on weight of cement slurry (BOWS) on the smart cement compressive strength and piezoresistivity behavior has been investigated. CO_2 was exposed to the cement slurry during initial mixing. After one day of curing, the piezoresistivity of the smart cement was 306% and with CO_2 exposure the piezoresistive behavior of the smart cement increased. Piezoresitivity of the smart cement exposed to 1% CO_2 was 374% at the failure, a 22% increase. Piezoresitivity of the smart cement exposed to 3% CO_2 was 468% at the failure, a 53% increase. The compressive strength of the smart cement was 1.81 ksi after one day of curing and CO_2 exposure decreased the compressive strength of the smart cement by 8% and 26% to 1.67 ksi and 1.34 ksi respectively for 1% and 3% of CO_2 concentration.

1. Introduction

In some wells, CO_2 may migrate from the storage formation back to the atmosphere through cement or along the interfaces between cement and casing or interfaces between cement and geological formation. This migration can affect the properties of the oil well cement [1]. 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 effect of different CO_2 concentrations of 0.1%, 1% and 3% based on weight of cement slurry (BOWS), which exposed to the cement slurry during initial mixing, on smart cement compressive strength and piezoresistivity behavior.

3. Materials and Methods

The test specimens were prepared using the API standards. API class H cement was used with water-cement ratio of 0.38. For all the samples 0.04% (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. 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. The smart cement slurry was exposed to different CO_2 concentration of 0.1, 1 and 3% BOWS after 10 minutes of mixing the cement slurry. After 1 day all the specimens were unmolded and cured for 28 days under water with the same CO_2 concentration they were initially exposed to.

4. Result and Discussion

The compressive strength of the smart cement was 1.81 ksi after1 day of curing. CO_2 exposure decreased the compressive strength of the smart cement. As shown in Fig. 1, the compressive strength of the smart cement exposed to 1% and 3% of CO_2 decreased to 1.67 ksi and 1.34 ksi respectively, 8% and 26%

reduction after 1 day of curing. As shown in Fig.1, after 1 day of curing, the piezoresistivity of the smart cement was 306%. Parameters *p* and *q* for the model were 15 and 13 respectively. As shown in Fig.1, CO_2 exposure increased the piezoresistive behavior of the smart cement considerably. Piezoresitivity of the smart cement exposed to 1% CO_2 was 374% at the failure, a 22% increase. As shown in Table 1, the model parameters of the p-q model for the 1% CO_2 Exposed Smart Cement were 7 and 10 for *p* and *q* respectively. Piezoresitivity of the smart cement exposed to 3% CO_2 was 468% at the failure, a 53% increase. As shown in Table 1, the model parameters of the p-q model for the 3% CO_2 Exposed Smart Cement were 0.17 and 4 for *p* and *q* respectively.
In order to represent the piezoresistive behavior of the hardened cement,Vipulanandan 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 material 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.

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

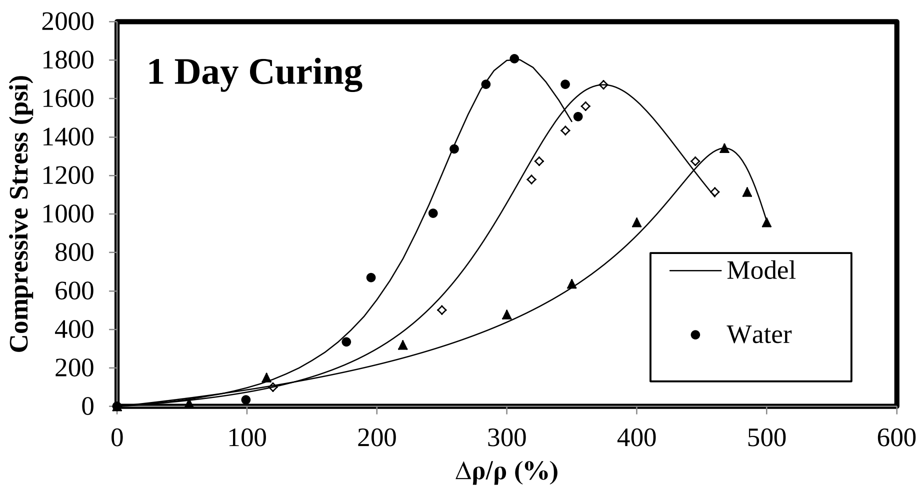

Figure 1: Piezoresistivity of CO_2 Exposed Smart Cement after 1 day of curing

Table 1: Model parameters of p-q model for evaluating the piezoresistivity behavior of the CO_2 Exposed Smart Cement after 1 day of curing

Cement	***1 Day Curing***			***Compressive Strength (psi)***	***Piezoresistivity at Failure (%)***
	$p_{1\,Day}$	$q_{1\,Day}$	R^2		
Smart Cement	15	13	0.99	1810	306
1% CO_2 + Smart Cement	7	10	0.99	1670	374
3% CO_2 + Smart Cement	0.17	4	0.99	1340	468

6. Acknowledgment

This study was supported by the Texas Hurricane Center for Innovative Technology (THC -IT).

7. References

1. Nils van der Tuuk Opedal, Malin Torseater, Torbjorn Vralstad, Pierre Cerasi. (2014). "Potential Leakage Paths along Cement-Formation Interfaces in Wellbores; Implications for CO2 Storage” Energy Procedia 51, pp. 56-64.