Curing of Smart Cement Contaminated with CO_2 during Initial Mixing

N. Amani and C. Vipulanandan, Ph.D., P.E.
Center for Innovative Grouting Material and Technology (CIGMAT)
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 0.1%, 1% and 3% CO_2 concentrations based on weight of cement slurry on the curing of the smart cement was investigated. Cement slurry was contaminated with CO_2 during initial mixing. The average initial resistivity of the uncontaminated cement slurry was 1.10 Ω.m. Exposing the cement slurry to 0.1%, 1% and 3% concentration of CO_2 resulted in a reduction in the initial resistivity to 1.03 Ω.m, 0.93 Ω.m and 0.90 Ω.m respectively. Curing of the smart cement under water for 28 days develped a resistivity of 17.0 Ω.m. Exposure of the smart cement to CO_2 reduced the development of the resistivity during 28 days of curing by 21%, 34% and 38% to 13.4 Ω.m, 11.3 Ω.m and 10.5 Ω.m respectively.

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 electrical resistivity.

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. 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 average initial resistivity of the cement slurry was 1.10 Ω.m. Exposing of the cement to 0.1%, 1% and 3% concentration of CO_2 resulted in a reduction in initial resistivity to 1.03 Ω.m, 0.93 Ω.m and 0.90 Ω.m respectively. Hence, CO_2 exposure with concentration of 0.1%, 1% and 3% resulted in a reduction of 6%, 15% and 18% respectively. The minimum resistivity of the smart cement slurry is 0.85 Ω.m which happened 85 minutes after mixing the sample. CO_2 exposure decreased the ρ_{min} of the smart cement slurry by 7%, 15% and 17% from 0.85 Ω.m to 0.79 Ω.m, 0.72 Ω.m and 0.70 Ω.m respectively for 0.1%, 1% and 3% of $CO2$ concentration. CO_2 exposure also delayed the hydration process. 0.1%, 1% and 3% of CO2 concentration delayed t_{min} by 15 minutes, 35 minutes and 45 minutes respectively. After 28 days of curing the smart cement under the water the resistivity reached to 17.0 Ω.m. CO_2 exposure reduced the development of the resistivity during 28 days of curing. 0.1%, 1% and 3% of CO_2 concentrated water reduced the resistivity of the cement by 21%, 34% and 38% to 13.4 Ω.m, 11.3 Ω.m and 10.5 Ω.m respectively after 28 days of curing.

In order to represent the electrical resistivity development of the cement, modified p-q model was used as followed:

$$\rho = \rho_{min}\left[\frac{q+(1-p-q)\left(\frac{t+t_0}{t_{min}+t_0}\right)+p\left(\frac{t+t_0}{t_{min}+t_0}\right)^{\left(\frac{p+q}{p}\right)}}{\left[\frac{t+t_0}{(t_{min}+t_0)}\right]}\right]$$

(1)

Where ρ is the electrical resistivity in Ω.m, ρ_{min} is the minimum electrical resistivity in Ω.m, t_{min} is the time corresponding to the minimum electrical resistivity (ρ_{min}) in minutes, t represents the curing time in minutes, t_0 is the model parameter and p and q are the hyperbolic time-dependent model parameters as follow:

$$p = p_0 + \frac{t}{A+B.t} \quad ; \quad q = q_0 + \frac{t}{A'+B'.t} \qquad (2, 3)$$

In which p_0, A, B, q_0, A' and B' are model parameters.

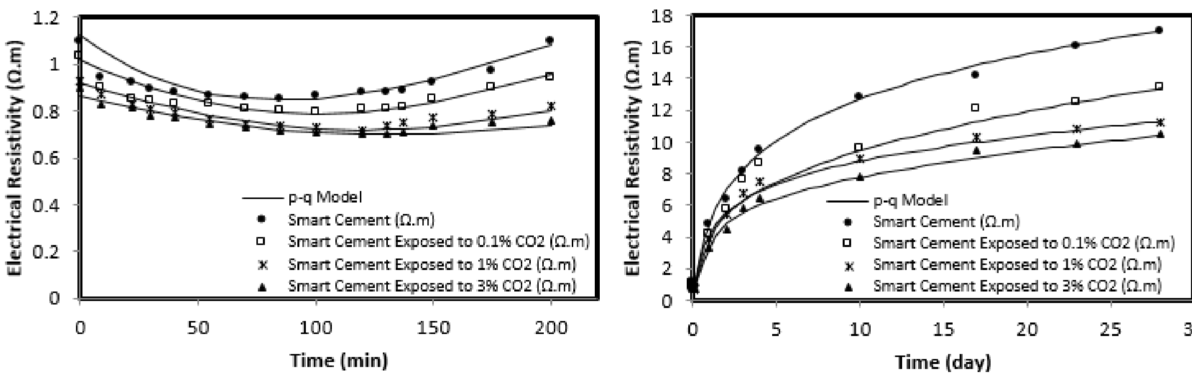

Figure 1: Development of electrical resistivity of smart cement exposed to different CO2 concentration during 28 days

Table 3. Electrical resistivity parameters of the smart cement exposed to different CO2 concentration

Smart Cement	q_0	A	B	p_0	A'	B'	t_0	t_{min}	ρ_{min}	R^2	$RMSE$ $\Omega.m$
Uncontaminated cement	2.4	350	0.8	1.0	127	0.02	240	85	0.85	0.99	0.30
0.1% CO_2 Exposed Smart Cement	0.7	500	1.5	0.10	803	0.23	180	100	0.79	0.99	0.36
1% CO_2 Exposed Smart Cement	0.4	3100	1.0	0.02	2442	0.19	170	120	0.72	0.99	0.30
3% CO_2 Exposed Smart Cement	0.3	1500	1.2	0.02	1994	0.27	165	130	0.70	0.99	0.22

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6. References

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