Effect of Nano $CaCO_3$ on the Piezoresistive Behavior of Smart Cement

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Abstract: The effect of adding 1% Nano CaCO3 (NCC) to the Smart cement was evaluated. Addition of 1% NCC to the smart cement reduced the initial resistivity. NCC modification also caused increment of rheological properties of the smart cement slurry. It also accelerated the hydration process. NCC increased the piezoresisitivity and also increased the compressive strength of smart cement.

1. Introduction:

Recent studies have used nano-particles because of their size, specific surface area and interface characteristic which can modify different properties of cementitious materials. Liu and Chen (2012) studied the effect of NCC on enhancement of compressive and flexural strength and also reduction in shrinkage of Portland cement. Sato and Beaudoin (2010) showed the accelerating behavior of NCC on hydration of the ordinary Portland cement, using different methods such as Isothermal Calorimeter, Thermogravimetric analysis (TGA) and X-ray diffractometry analysis (XRD). They suggested that the seeding effect of NCC particles which leads to increment in rate of nucleation of calcium silicate hydroxide gel caused the strength enhancement. Another effect of NCC is that it increased electrical resistivity of cementitious materials which was presented by Hosseini et al. (2014).

2. Objective:

The overall objective of this study was to investigate the effect of 1% NCC additive on the physical and electrical properties and piezoresistive 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 0.075% (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 1% NCC. 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 average initial resistivity of the cement slurry was 1.07 Ω.m. Adding 1% of NCC to the cement reduced the initial resistivity from 1.07 Ω.m to 0.85 Ω.m, a 21% reduction. Adding 1% of NCC reduced the minimum resistivity of the smart cement slurry from 0.95 Ω.m to 0.77 Ω.m, a 19% reduction. NCC modification also reduced t_{min} by 30 minutes which is owing to the fact that NCC accelerated the hydration process because of its seeding effect. After 28 days of curing the smart cement under the water the resistivity reached to 12.2 Ω.m. Adding 1% of NCC can improve the resistivity of the smart cement to 28.5 Ω.m, a 134% increase, after 28 days of curing under the water. After 1 day of curing, the piezoresistivity of the smart cement was 375%. Adding 1% of NCC enhanced the piezoresistivity by 37% which leads to have 514% piezoresistivity after 1 day of curing. After 28 days of curing, the piezoresistivity of the smart cement was 204%. Adding 1% of NCC caused enhancement in piezoresistivity by 28% which leads to have 260% piezoresistivity after 28 days of curing under water. In order to represent the piezoresistive behavior of the hardened cement, p-q model was used as followed:

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

Where 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.

Table 1. Electrical resistivity parameters of the modified and unmodified smart cement slurries with and without 1% of NCC modification

Cement	ρ_0 $(\Omega.m)$	ρ_{min} $(\Omega.m)$	t_{min} $(minute)$	ρ_{24} $(\Omega.m)$	$\frac{\rho_{24}-\rho_{min}}{\rho_{min}}$
Smart Cement	1.07	0.95	85	2.86	201%
1% NCC Modified Smart Cement	0.85	0.77	60	4.02	341%

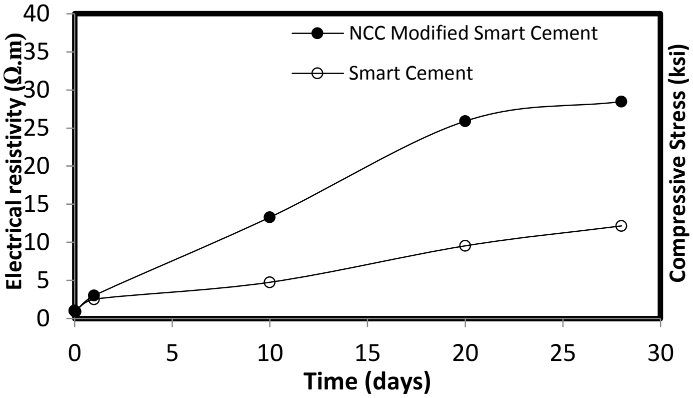

Figure 1. Electrical resistivity development of the smart cement with and without 1% of NCC modification during 28 days of curing under water

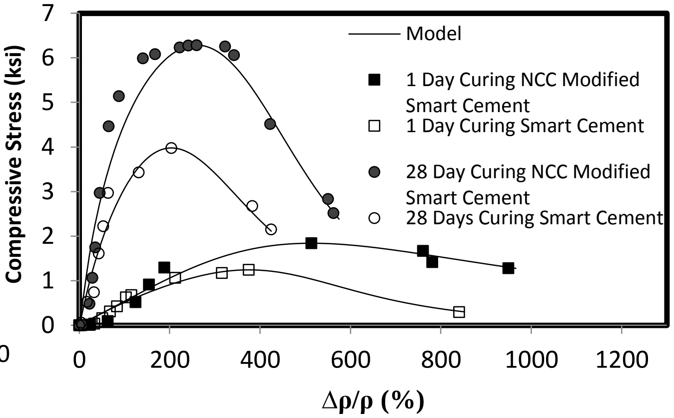

Figure 2. Piezoresistivity behavior of the smart cement with and without 1% of NCC modification after 1 and 28 days of curing under water

Table 2. Model parameters of p-q model for evaluating the piezoresistivity behavior of the smart cement with and without 1% of NCC modification after 1 and 28 days of curing under water

Cement	*1 Day Curing*			*28 Days Curing*		
	$p_{1\,Day}$	$q_{1\,Day}$	R^2	$p_{28\,Days}$	$q_{28\,Days}$	R^2
Smart Cement	0.15	0.57	0.97	0.13	0.40	0.94
1% NCC Modified Smart Cement	0.40	0.67	0.95	0.069	0.29	0.95

6. Acknowledgements:

This study was supported by the Center for Innovative Grouting Materials and Technology (CIGMAT), University of Houston, Houston, Texas with funding from the Ultra Deepwater Program DOE/NETL/RPSEA (Project No. 10121-4501-01).

7. References

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