Long-Term Piezoresistive Behavior of Smart Concrete

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 behavior of smart cement composite (smart concrete) with 75% of gravel was investigated. The piezoresistivity of the smart cement composite with 75% gravel was 217% after 1 day of curing. After 28, 180 and 365 days of curing, the piezoresistivity of the 75% gravel smart concrete reduced by 44%, 53% and 58% to 121%, 102% and 91% respectively.

1. Introduction

Smart structures play significant role in maintaining civil infrastructure systems. The sensing provides an electrical, optical or acoustical response to any elastic or inelastic deformation in real time during dynamic loading. Several studies were done on ultrasonic cement analyzer as the only continuous characterization method for concrete; however, this method is hardly applicable in field studies. Vipulanandan et al. (2015) suggested electrical resistivity measurements as a simple, economical and nondestructive method for monitoring the long-term characterization of smart concrete. They also studied the piezoresistive behavior of smart concrete 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 piezoresistive behavior of smart cement composite (smart concrete) with to 75% gravel based on total weight of slurry.

3. Materials and Methods

Specimens have been prepared using class H cement with water-cement ratio of 0.38 gravel percentage of 75% based on total weight of slurry. For all the samples 0.04% (By the weight of total, BWOT) of conductive filler (CF) was added to the mortar in order to enhance the piezoresistivity of the cement and to make it more sensing. After mixing, the mortar was 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 measure the piezoresistivity of the specimens. Specimens were cured for 1 year under relatively high humidity of 90% and after 1, 28, 180 and 365 days that they were tested by Tinious Olsun device by displacement rate of 0.005 inches per minute. While doing the compression test, the change in resistance was measured continuously using the LCR meter. To minimize the contact resistances, the resistance was measured at 300 KHz using two-wire method.

4. Result and Discussion

As shown in Fig.1, the compressive strength of the 75% gravel smart concrete increased was 1700 psi. The compressive strength of the 75% gravel smart concrete increased by 159%, 229% and 241% respectively to 5600 psi, 5600 psi and 5600 psi after 28, 180 and 365 days of curing.

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.

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

The piezoresistivity of the 75% gravel smart concrete was 217% after 1 day of curing. After 28, 180 and 365 days of curing, the piezoresistivity of the 75% gravel smart concrete reduced by 44%, 53% and 58% respectively to 121%, 102% and 91%.

Variation of piezoresistivity of the smart concrete with curing time was modeled using the Vipulanandan Correlation Model as follows:

$$\frac{\Delta R}{R} = \left(\frac{\Delta R}{R}\right)_0 - \frac{t}{A+Bt} \quad (2)$$

In which $\left(\frac{\Delta R}{R}\right)_0$ is the piezoresistivity after 1 day of curing which is 217% for 75% gravel smart concrete.

Model parameters A and B were 0.0477 and 0.0071 respectively for 75% gravel smart concrete.

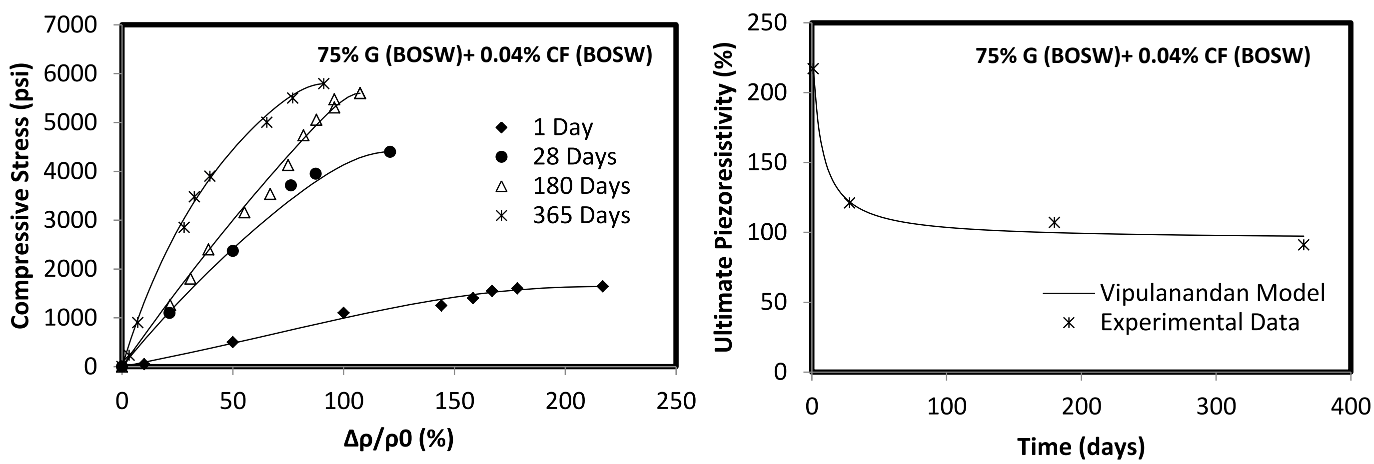

Figure 1: Piezoresistive behavior of the smart concrete after 1 day of curing

Table 1: Model parameters of p-q model for evaluating the piezoresistive behavior, Compressive Strength and Ultimate Piezoresistivity of the smart concrete

Curing Time	*p*	*q*	R^2	*Compressive Strength (psi)*	*Ultimate Piezoresistivity (%)*	*RMSE (psi)*
1 Day Curing	0.44	0.85	0.99	1700	217	65
28 Days Curing	0.1	0.65	0.98	4400	121	138
180 Days Curing	0.05	0.8	0.98	5600	107	139
365 Days Curing	0.045	0.42	0.99	5800	91	121

5. Acknowledgements

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6. References

1. Vipulanandan, C., and Garas, V. (2008) "Electrical Resistivity, Pulse Velocity and Compressive Properties of Carbon Fiber Reinforced Cement Mortar," Journal of Materials in Civil Engineering, Vol. 20, No. 2 , pp. 93-101.