Investigating the Piezoresistivity Behavior of Smart Concrete

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Abstract: The behavior of smart concrete with different percentages of gravel was investigated. Addition of the gravel reduced the ultimate piezoresistivity. The ultimate piezoresistivity of smart concrete with 10%, 50% and 75% of gravel were decreased by 6%, 23% and 42% respectively, from 375% for smart cement without any gravel to 354%, 288% and 217%

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 concrete with up to 75% gravel based on total weight (BOTW).

3. Materials and Methods

Specimens have been prepared using class H cement with water-cement ratio of 0.38 and different gravel percentages of 10%, 50% and 75% (BWOT). 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 day under relatively high humidity of 90% and after 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

The compressive strength of the cement was 1.24 ksi after1 day of curing. Adding 10%, 50% and 75% of gravel to smart cement increased the compressive strength by 12%, 28% and 32% to 1.39 ksi, 1.59 ksi and 1.64 ksi respectively. As shown in Fig.1, after 1 day of curing, the piezoresistivity of the smart cement was 375%. Parameters p and q for the model were 0.68 and 0.61 respectively. The ultimate piezoresistivity of smart concrete with 10%, 50% and 75% of gravel were decreased by 6%, 23% and 42% respectively to 354%, 288% and 217%. As shown in Table 1, the model parameters of the p-q model for the smart concrete with 10% of gravel are 0.55 and 0.72, with 50% are 0.51 and 0.79and with 75% are 0.44 and 0.85 for p and q respectively.

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.

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

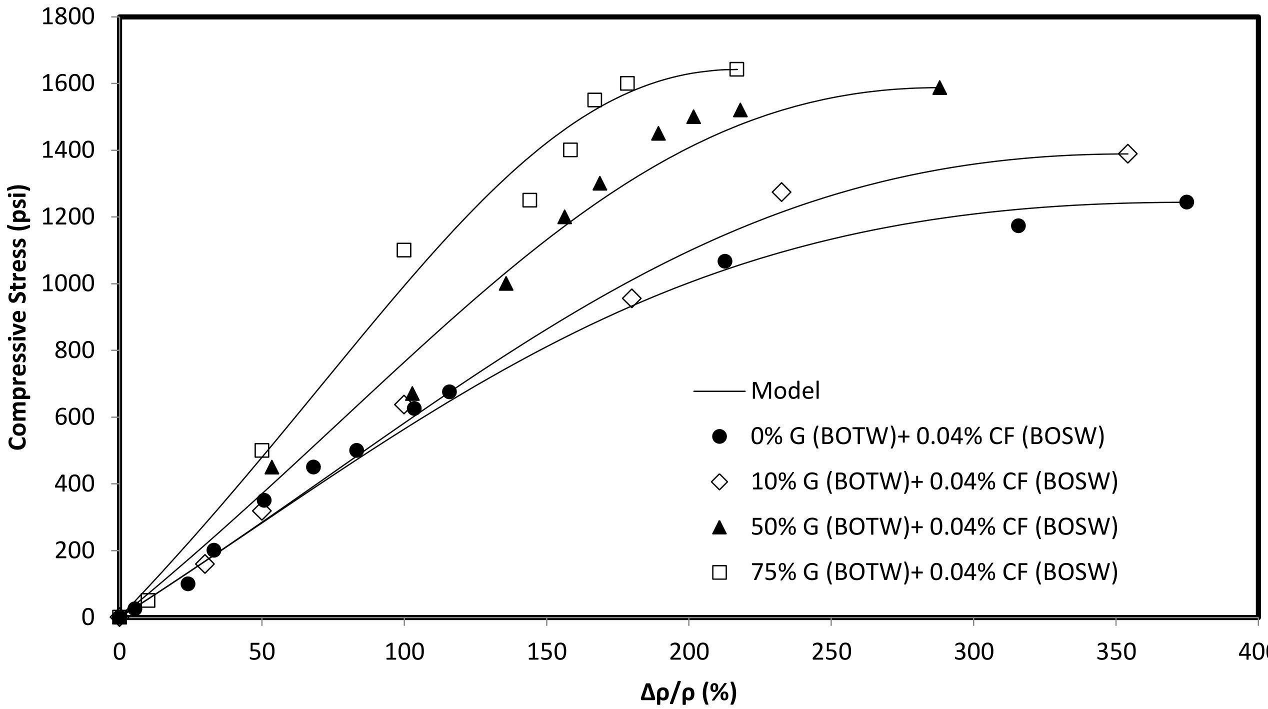

Figure 1. Piezoresistive behavior of the smart concrete after 1 day of curing

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

Cement	***1 Day Curing***			***Compressive Strength (psi)***	***Ultimate Piezoresistivity (%)***
	$p_{1\ Day}$	$q_{1\ Day}$	R^2		
Smart Cement	0.68	0.61	0.99	1240	375
10% Gravel Smart Concrete	0.55	0.72	0.99	1390	354
50% Gravel Smart Concrete	0.51	0.79	0.99	1590	288
75% Gravel Smart Concrete	0.44	0.85	0.99	1640	217

6. Acknowledgements

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7. 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.