Parametric Study Using Vipulanandan Curing Model

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Abstract

In this study, a parametric study on the Vipulanandan curing model was conducted by changing the initial time constant t_0. Results showed that as the initial time increases as the electrical resistivity of smart cement decreases after 28 days of curing. In addition, results also suggest that Vipulanandan's model accurately predicts the curing behavior of the Smart Cement.

1. Introduction:

Proper curing is essential to ensure the integrity of the smart cement during placement operations and the entire service life of the buildings (Vipulanandan, 2021). At present, there is no reliable technology available to monitor cementing operations in real-time from the initial curing time and throughout the service life of the cement (Vipulanandan et al., 2014). This challenge might be delivered by creating types of cement that demonstrate sensing abilities. Electrical resistivity is a non-destructive test that can be a sensible technique to establish cement properties. The technology is based on the nonlinear p-q model developed by (Vipulanandan et al., 1990). This model was adapted to compute the change in resistivity induced by curing time. This study is dedicated to investigating the parametric study of the curing behavior of smart cement and validating the p-q model presented in this report using experimental data.

2. Objective

The main objective was to conduct a parametric study on the Vipulanandan curing model of smart cement. The specific objectives of this study are the following:

(i).Study the effect of initial time constant t_0 on the electrical resistivity of smart cement.

(ii).Model the cement curing behavior using Vipulanandan curing model.

3. Methodology

Commercially available Class-H cement was used for characterizing the cast material. The water to cement ratio used was 0.4. The cement slurry was prepared using a mixer by adding the cement into the water. After mixing, cement specimens were prepared using cylindrical molds. The Cylindrical molds are 2 inches in diameter and have a height of 4 inches as shown in Figure 1a. Electrical resistivity measurements using a commercial LCR device at 300 kHz were performed.

(a) (b)

Figure 1: Electrical resistance measurements (a) Test samples, and LCR device

Vipulanandan curing model: This model was performed to predict the electrical resistivity of cement during hydration of the cement as shown in Figure 2.

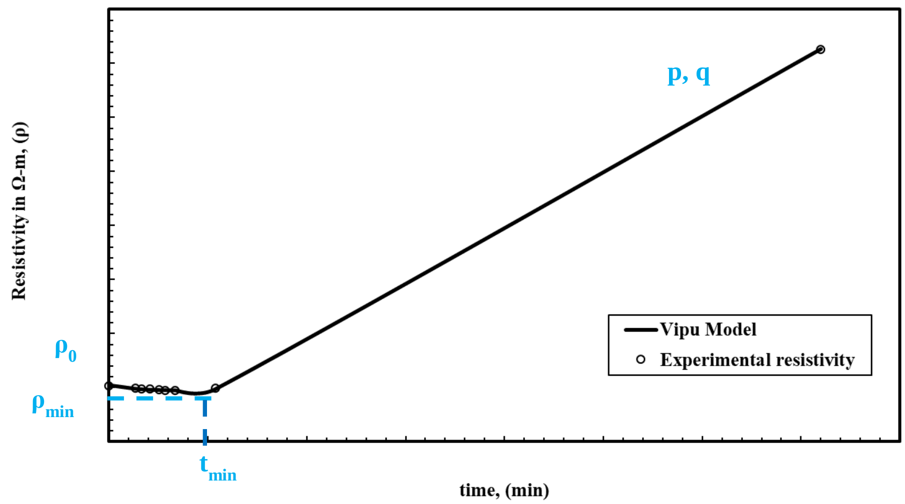

Figure 2: Typical changes in the resistivity during the hydration of cement with time

This Vipulanandan Cueing Model is represented as follows:

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

where ρ is the electrical resistivity (Ω- m); ρ_{min} is the minimum electrical resistivity (Ω- m); t is the curing time (min), t_{min} is the time corresponding to minimum electrical resistivity (ρ_{min}); parameters p, t_o, and q are model parameters. In this study, a parametric study was conducted by changing the initial time constant t_0 between 10 to 50 minutes with increment of 10 minutes.

4. Results:

Electrical Resistivity

The initial resistivity of the cement was 0.93 Ω-m. After 28 days of curing, the resistivity of 10 minutes initial time constant t_0 was 28 Ω-m, which is the highest compared to the remaining cases as shown in Figure 3. Increasing the initial time constant t_0 from 10 to 50 minutes reduces the electrical resistivity to 22 Ω-m, which is about 55% reduction. This could be attributed to the moisture loss and weight change due to bleeding during the curing time. The Vipulanandan curing model parameters p, q, and t_o are summarized in Table 1. The coefficient of determination (R^2) was about 1, and the root-mean-square error (RMSE) was around 1-1.9 Ω-m after 28 days of curing.

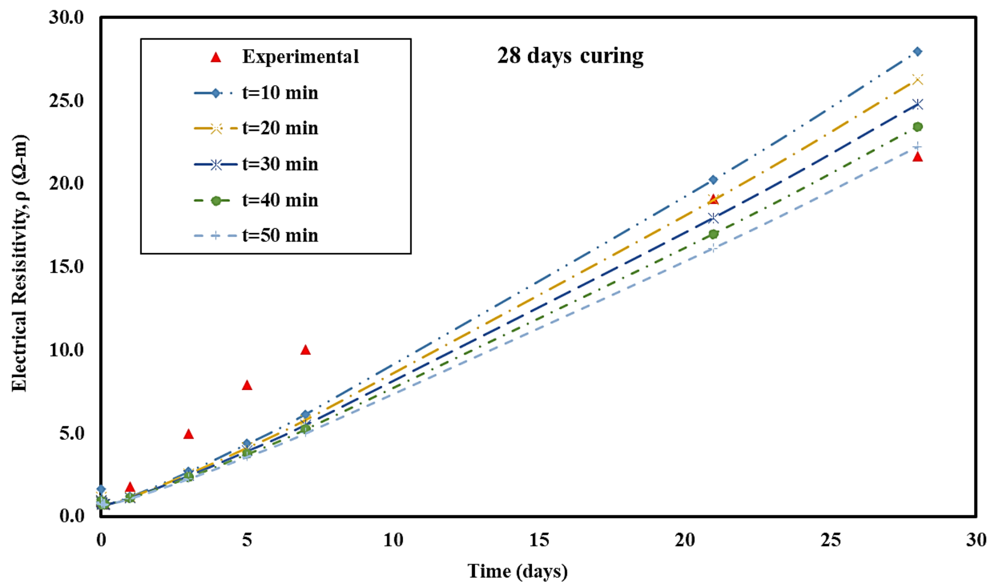

Figure 3: Parametric study on the electrical resistivity of Class-H cement up to 28-days of curing with the time parameter (*t_o*) from 10 to 50 minutes

Table 1: Vipulanandan curing model parameters for the different initial time to

The initial time constant (min.)	to	10	20	30	40	50
Minimum Conductivity at tmin	1/ ρ			1.396		
Minimum Time (min.)	t min			165		
Model Constant	q=Es/Ei	0.084	0.084	0.084	0.084	0.084
Model Constant	p	0.073	0.073	0.073	0.073	0.073
Constraint	p+q	0.157	0.157	0.157	0.157	0.157
Constraint	q/p	1.151	1.151	1.151	1.151	1.151
Coefficient of determination	R^2	0.993	0.994	0.995	0.995	0.994
Root-mean-square error	RMSE	1.931	1.910	1.893	1.912	1.011
Resistivity at 28 days - (Ω-m)	ρ	27.96	26.27	24.77	23.43	22.21

5.Conclusions

From this study, the following conclusions are advanced:

(1). Increasing the initial time constant t_0 from 10 to 50 minutes reduces the electrical resistivity to about 55% due to bleeding during the curing time.

(2). Vipulanandan curing model predicted the measured resistivity very well.

6. Acknowledgments:

This study was supported by the Center for Innovative Grouting Materials and Technology (CIGMAT) and Texas Hurricane Center for Innovative Technology (THCIT), University of Houston, Houston.

7.References:

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