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Finite Element Analysis of Electrode Distribution Effect on the Resistance Measurement of Cement Paste

Lin CHI[1, 2, 3]*, ZhaoDe Zhi[1,2,3] and Zheng WANG[1, 2, 3]

[1]*School of Civil Engineering, Harbin Institute of Technology, China*

[2]*Key Lab of Structures Dynamic Behavior and Control of the Ministry of Education, Harbin Institute of Technology, China*

[3]*Key Lab of Smart Prevention and Mitigation of Civil Engineering Disasters of the Ministry of Industry and Information Technology, Harbin Institute of Technology, China*

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***Corresponding author:** Lin CHI, Harbin Institute of Technology, China

Abstract

In this study, the electrode distribution effect on the resistance measurement of cement paste is investigated. All three-dimensional of the electric field strength and electric potential of the cement pastes with three electrode distribution were simulated with ANSYS Maxwell®. The magnitude and direction of the electric fields surrounding three sets of charged electrodes were also determined. The low electric field intensity of each model is further calculated, and the results illustrate that the resistance measured from the cement paste with the electrodes located at the trisection line is much closer to the real resistance value, which provides us a new application of the electrode distribution on the measurement of cement paste or concrete resistance in the practical engineering project.

Keywords: Electrode distribution; ANSYS Maxwell simulation; Electrical resistance

Introduction

Electrical resistance is an important characteristic parameter that can be related to its durability and mechanical strength development, since the electrical resistance can reflect the microstructure variation in the cement matrix or concrete structures [1]. There are several methods to measure the electrical resistivity or conductivity in cement or concrete matrix, like direct current method, alternating current impedance spectroscopy, non-contact electrical resistivity measurement or non-contact impedance measurement, and four points Wenner probe [2]. In practical engineering, two-point electrodes served as the simplified electrode plates are applied as the positive or negative electrode for resistance measurement. However, the electrode distribution effect on the resistance measurement of cement paste is rarely investigated. Therefore, in this study, the finite element analysis is applied to study the electrode distribution effect on the resistance measurement.

Modeling

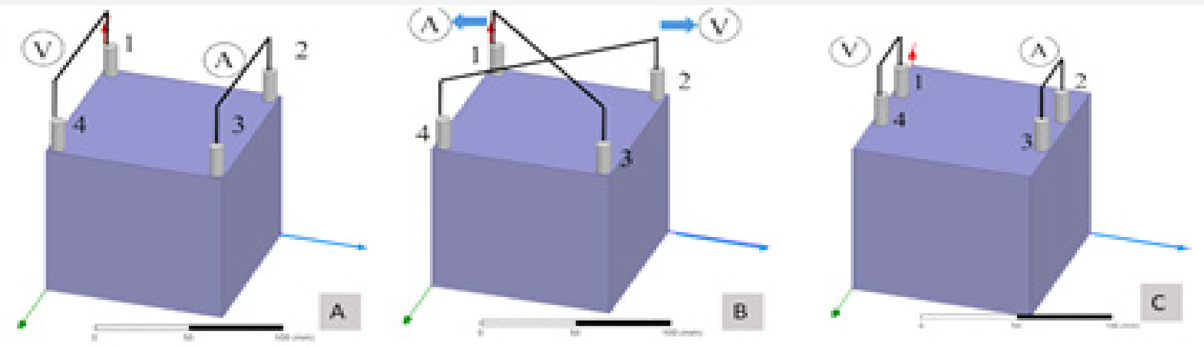

Figure 1: The distribution of the four electrodes embedded in the cement paste. V and A represent the positive and negative electrodes, respectively.

Four electrodes (304 stainless steel Diameter 8mm Length12mm) were embedded in the cement matrix (OPC cement paste with w/c= 0.4). The distributions of the four electrodes were listed in Figure 1. In Figure 1 A and C, the electrodes were placed at each corner of the samples. In Figure 1 B, each two of the electrodes were placed at the trisection of one side of the specimen. Specimens were modelled with ANSYS Maxwell V16 Software from ANSYS. For this model analysis, the cement paste can be regarded as a composite material at a larger length scale where each phase is a continuum material with specific properties [2]. The modelling of dynamic electric field and potential is carried out by setting the excitations assignment in the Electric Transient. A sinusoidal AC voltage is set for the positive electrode at 10mV intervals from the negative to the positive electrode in each set (the negative electrode was at ground potential). The initial time is set as 0.01s and stopped until 5s. All three-dimensional of the electric field strength and electric potential of the cement pastes with different electrode distribution were computed. The magnitude and direction of the electric fields surrounding three sets of charged electrodes were also determined (Figure 1).

Results and analysis

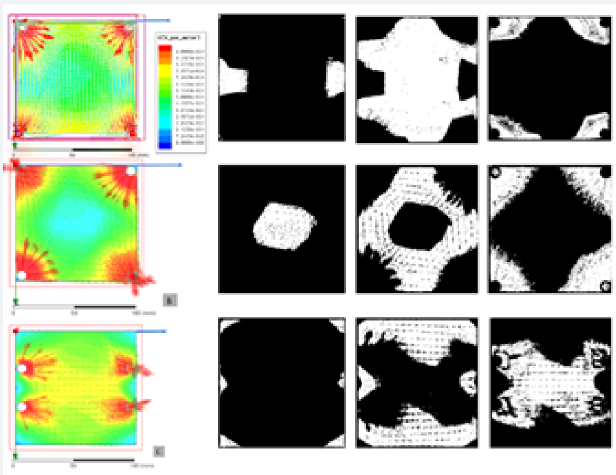

Figure 2: All three-dimensional of the Electric field strength and electric potential (color scale) and direction (arrows) of the cement paste with three models of electrodes distribution. Local region area (divided by three E- field range) measurement by Image-Pro Plus Software.

The electric field strength and electric potential (color scale) and direction (arrows) of the cement paste with three models of electrodes distribution are shown in Figure 2. The average magnitude of the electric field intensity along the edge of the electrodes is significantly higher compared with the electric field intensity in the cement paste matrix. When the four electrodes are located in each corner of the cubic (Figure 2 A or C), the low electric field intensity (known as blue regions) appears at the waist or the center area of cement paste. When the four electrodes located at the trisection point along the X axis direction, the blue region is only appeared at the margin of the cement paste. The ratio of the low electric field intensity area and the total electric field intensity area for each model is further analyzed by a commercial software Image-Pro Plus from Media Cybernetics. The geometric area of electric field can be calculated. The final results obtained from low electric field intensity area illustrates that the resistance measured from the cement paste with the electrodes located at the trisection line is much closer to the real resistance value [3,4].

Conclusion

The resistance measured from the cement paste with the electrodes located at the trisection line is much closer to the real resistance value. There is a good agreement found between the finite element results for the electrode distribution in cement paste. It may provide us a new application of the electrode distribution on the measurement of cement paste or concrete resistance in the practical engineering project.

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