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EXTENDED ABSTRACT

Electrical Current Flow Modeling Using Meshless Method in Homogeneous Concrete

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1. Introduction

Concrete is the most widely used construction material in the world for many decades. Old existing structures are deteriorated and needed inspection and repair. Electrical methods, which are inexpensive and easy to handle, are well known as non-destructive inspection methods. They can give information about the position, size, and orientation of inclusions like bar and fiber, condition of corrosion, state of humidity and probable corrosive ions, and the degree of cracking in concrete. Both alternate and direct currents (AC & DC) can be used in electrical resistance measurement (ERT). A major problem of the DC method is the measurement error produced by a polarization of the specimen. In AC methods the frequency should be kept as low as possible to avoid the inductance effects of long connecting cables and also the frequency has to be high enough to avoid electrode polarization effects. In ERT, electric current is injected through electrodes, and the voltage produced on the object surface is recorded using several electrode pairs. Then an estimate of the spatial distribution of conductivity is mapped (Karhunen et al., 2010).

The finite element method (FEM) has been widely applied for the numerical solution of governing physical-based partial differential equation of electric current flow (Hou and Lynch, 2009). FEM needs a mesh in the solution domain or on its boundary which makes some difficulty in highly irregular and complex geometry. The meshless method is an alternative solution that was developed to establish a system of (linear) algebraic equations for the entire domain of the problem without creating pre-defined meshes. In this study meshless method is used due to the following advantages (Nourani and Babakhani, 2012): 1) It doesn't require a domain and boundary meshing; 2) there is no need for integration in domain and boundary; 3) point location is the only variable in RBF functions which makes it suitable for high dimensional problems; 4) RBF is easy to code and implement. Among various types of meshless methods, multi-quadratic radial basis function formulation (MQ-RBF) is mostly utilized. One challenging issue related to the MQ-RBF method is the calibration of shape coefficient which is a case-sensitive parameter. This research proposed a Bayesian statistical theorem for the calibration of shape coefficient.

ERT problems are ill-posed inverse problems that are very sensitive to a moderate error in modeling and uncertainties like unknown conductivity distributions and shape coefficient. In this paper, we make use of MQ-RBF to numerically solve differential equations of ERT formulation in two dimensions. Using Bayes' theorem, the related inverse problem changes to a statistical nonlinear problem in which the unknowns are the conductivity distribution and shape coefficient. An experimental study was conducted to validate the proposed method. In order to solve the optimization problem, we employ the Markov chain-Monte Carlo method (MCMC). Although the computational cost of MCMC can apparently be high, by taking appropriate prior, results will quickly tend to accurate reconstruction.

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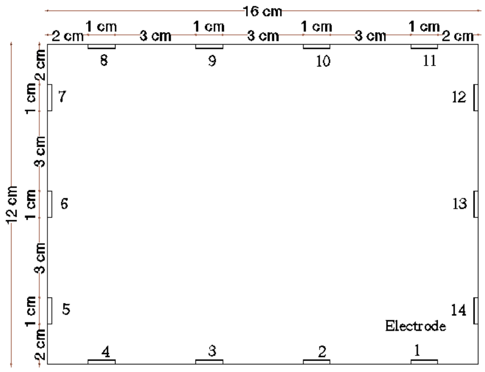
2. Materials and Methods

2.1. Experimental setup

In ERT we need some potential measurements on the outer face of the specimen. To this end, electric current is injected through prepared rectangle concrete samples and the electrical potential in different boundary electrodes were measured by tomography device. Injecting current flow through the specimen is done via pair electrodes in 3 main configurations. Opposite, adjacent, and one-in-a-row pairs and in total, 35 configurations were studied. Configuration 2 and 9 correspond to pair electrodes 2 & 10 and 2&3, respectively (Fig. 1).



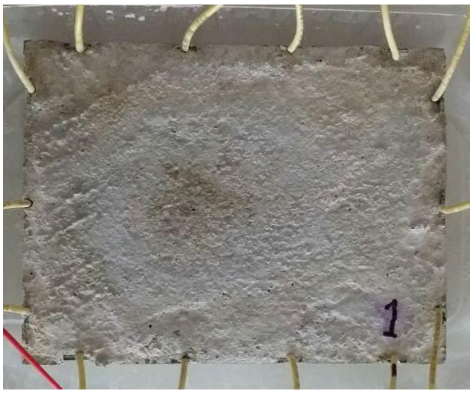


Fig. 1. Concrete specimen (right), dimensions of specimen and number of electrodes (left)

2.2. Numerical Study

In order to analyze gathered laboratory data, the shape coefficient was calibrated using the Bayesian method and afterward, potential in any point inside the specimen was calculated by a meshless method. To evaluate the ability of the meshless method, the results got compared with Comsol multiphysics modeling results.

3. Results and discussion

The first step in the meshless method is to calibrate the shape coefficient which was done by Bayes' theorem. For example, Fig. 2 shows the optimized shape coefficient for configurations 2 and 9.

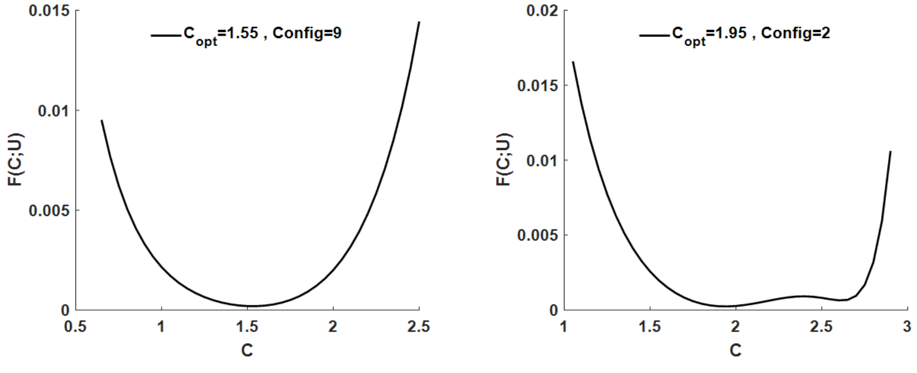


Fig. 2. Optimum shape coefficient of configuration 2 (Right) and configuration 9 (Left)

Results show that among 3 main pair configurations the lowest deviation of shape coefficient is for opposite pairs and the highest deviation of shape coefficient is for adjacent pairs. Also, results show that the efficiency of the meshless method is more than the Comsol model by 8 percent.

4. Conclusions

Electrical methods are well known as non-destructive inspection methods. In this research meshless method in conjunction with the Bayesian theorem was proposed for the solution of deferential equation of electric current flow in concrete. It's concluded that the best agreement is obtained in the opposite pair configuration. Results showed that the meshless method is reliable in the electrical tomography of concrete.

5. References

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