Can Electrical Resistance Tomography be Used to Monitor the Distribution of Moisture in Cement-Based Materials?

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Abstract. It is important to develop a tool to monitor moisture distribution in cement-based materials, because freeze-thaw of concrete, corrosion of steel bars, carbonization and other problems occur in the presence of water. In this paper, the feasibility of monitoring water distribution in cement-based materials by electrical resistance imaging (ERT) is studied. In ERT technology, the resistivity distribution is reconstructed by detecting the voltage at the boundary of the test block, and the structure and state of the object are presented by the image. The experimental results show that ERT technology can monitor the moisture distribution and outline in cement-based materials.

Keywords: ERT, Cement-based materials, Water distribution

1. Introduction

The ability to prevent water intrusion is an important characteristic of the durability of concrete structures, because the durability of concrete largely depends on its water transfer rate. At present, many advanced methods have been developed to monitor water distribution in cement-based materials, including nuclear magnetic resonance imaging [1-3], electromagnetic radiation attenuation (e.g. gamma ray [4-6], X-ray [7-9] and electron imaging [10-12]) and electrical methods [13-16]. The above methods have their advantages and limitations. For example, nuclear magnetic resonance, gamma-ray, X-ray and neutron imaging have higher spatial resolution, but they are invasive methods with high cost and large radiation, usually confined to small samples and laboratories. In contrast, the spatial resolution of electrical methods is low, but they have the advantages of non-invasive, low cost, easy operation and so on.

Electrical resistance tomography (ERT) is a powerful tool for monitoring water flow in concrete. At present, ERT has been used to monitor soil water infiltration [17], Danny et al. [14,15] to study the feasibility of monitoring concrete water infiltration by ERT. The purpose of this study is to investigate whether ERT can provide feasible information about water distribution in the case of uneven flow.

2. Materials and Methods

2.1. Electrodes

In this experiment, a fully embedded circular array measuring electrode array is designed. The array has 16 electrodes. The electrodes of this experiment are made of stainless steel sheets with a length of 16mmx12mmx0.4mm. Before the test, the electrode sheet is welded to the wire, and the electrode sheet is fixed on a special mold with hot melt adhesive, and then the specimen is poured, as shown in...
Figure 1. The characteristic of the electrode is that it can ensure the effective contact between the electrode and the specimen, the test is more accurate, and the electrode is relatively simple to make. The shortcoming of the electrode is that it is easy to deviate from the position of the electrode.

Figure 1. Embedded electrode array

2.2. Sample Preparation
In this paper, 42.5 cement and China ISO standard sand are used to make cement mortar blocks with water cement ratio of 0.6. High water cement ratio is used to increase the capillary porosity of mortar, thus increasing the capillary transport rate in the material, which will effectively reduce the experimental time. The agitated mortar is poured in a short cylindrical mold with a circular radius of 100mm and a height of 40mm. The top of the test block is formed by a plastic foam embedded in size of 100mmx20mmx20mm to form a rectangular groove with water. The well-made test block is shown in Figure 2.

Figure 2. Prepared test block

After the test block is poured, the standard curing box is used to curing and pouring the test block. The curing temperature is 20±2°C, the relative humidity is 90%. After 24 hours, the test block is taken out and placed indoors for natural curing. The indoor temperature is 13°C~20°C, and the relative humidity is 13%~40%. After the test block is cured, 40ml water is added into the groove and the top of the test block is sealed with thin transparent tape to avoid evaporation of moisture during the test. During the experiment, we measured the four time periods of 10min, 20min, 40min and 80min.

2.3. Electrical Resistance Tomography Imaging
According to the different resistivity of the material in the tested matrix, the material distribution in the sensitive field is obtained by analyzing the resistivity distribution of the material in the sensitive field. That is, when the resistivity distribution in the field changes, the potential in the field also changes, resulting in a corresponding change in the detection voltage (current) around the field. This means that the change of the boundary measurement voltage (current) in the field can reflect the change of the resistivity in the matrix. The resistivity distribution in the field can be reconstructed by solving the
inverse problem and image reconstruction algorithm, and then the object can be detected visually. The theoretical framework of this imaging method is shown in Figure 3.

![Figure 3. Theoretical framework of electrical resistance imaging](image)

The system adopted in this paper is based on the US National Virtual Instrument to realize the collection, test and control of the measured matrix data. As a highly flexible and accurate modular instrument, virtual instrument can control the instrument with a flexible and efficient graphical programming language, thus shortening the development cycle of the instrument and making the system more stable. The whole resistivity tomography system is based on the National Instrument PXI platform (composed of PXI controller, PXI chassis, mold heat switch, voltage source, voltage-controlled current source and voltage acquisition module). The data acquisition system based on LabVIEW programming is used to collect and extract the information carried by the electrical signals in the detected matrix, and the MATLAB is used as the data calculation and image reconstruction tool to realize the visual presentation of the object. The schematic diagram of the resistivity tomography platform is shown in Figure 4.

![Figure 4. Schematic diagram of resistivity tomography](image)

3. Results and Discussion
The ERT reconstructed image is shown in Figure 5. From the images of 10 and 20 minutes, it can be seen that the position and shape of the water flow are roughly the same as that of the specimen wetted by water visible to the naked eye. From the images of 40min and 80min, we can see the obvious uneven diffusion of water flow and tilt to the upper part. This may be due to the uneven porosity in the test block.
4. Conclusions
In this paper, the feasibility of electrical resistance tomography (ERT) in monitoring moisture distribution in cement-based materials is studied. The ERT experiment of mortar influent process was carried out. The experimental results of this study show that the ERT technology can provide information about the moisture distribution in the cement-based materials, which strongly supports the feasibility of monitoring the moisture distribution in the cement-based materials by the ERT technology.

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