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Consideration of Boundaries on Electrical Method

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ABSTRACT

A variety of lab-scale researches has been conducted with the electrical method to estimate the physical and chemical properties of the geo-materials. The measured data near the boundaries is not governed by the basic electrical theories. Experimental test were performed in cubic container and the methods that can reflect the boundary effect is suggested. The proposed methods can expect the measured data.

1. INTRODUCTION

Many researchers have carried out experimental tests to identify the ground characteristics such as porosity and saturation using the electrical resistivity (Archie, 1942). In laboratory scale tests, the size of the container is limited due to the lack of the fund and the test space. However, it is reported that the electrical resistivity values were affected by the boundary condition of the container in fixed size of the container (Park et al., 2017). The electrical resistivity values were raised when the electrodes approached the boundaries. They discussed that the phenomenon was oriented by the boundaries, however, there was no theoretical explanations. In this study, the theoretical analysis of the boundary condition will be conducted.

2. IMAGE METHOD

Valdes (1954) suggested the image method. This method assumed that the imaginary electrodes can play a role of the boundaries (Fig. 1). The imaginary electrode is placed in same distance from the electrode to the boundary but the opposite side of the real electrode. This sign of the imaginary electrode determined the boundary.

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Telford et al. (1990) considered the electrical resistivity of each medium to obtain the electric potential near the boundary as the following equation.

$$V_1 = \frac{I\rho_1}{4\pi}\left(\frac{1}{r_1}+\frac{k}{r_2}\right) \tag{1}$$

where ρ_1 is the electrical resistivity of the medium 1, ρ_2 is the electrical resistivity of the medium 2, r_1 and r_2 are the distance from the current electrode C_1 and C_2 and k is $(\rho_2-\rho_1)/(\rho_2+\rho_1)$.

The electrical resistance can be obtained with the potentials from the each electrodes (Telford et al., 1990).

$$R = \frac{V_1 - V_2}{I} \tag{2}$$

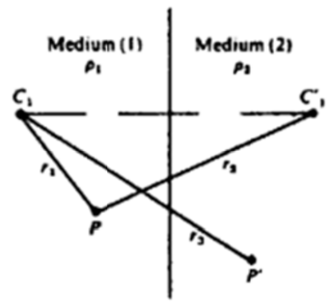


Fig. 1 Image electrode near the boundary (Telford et al., 1990)

3. RESISTOR GRID METHOD

The second method is a resistor grid method. In 2D square container, it is possible to assume the medium in the container is combination of the resistors (Fig. 2). Since Cserti (2000), there are lots of attempts to derive the system resistance of the resistor grid. In 2D square resistor grid, the electrical resistance of two point can be determined as the following equation (Wu, 2004).

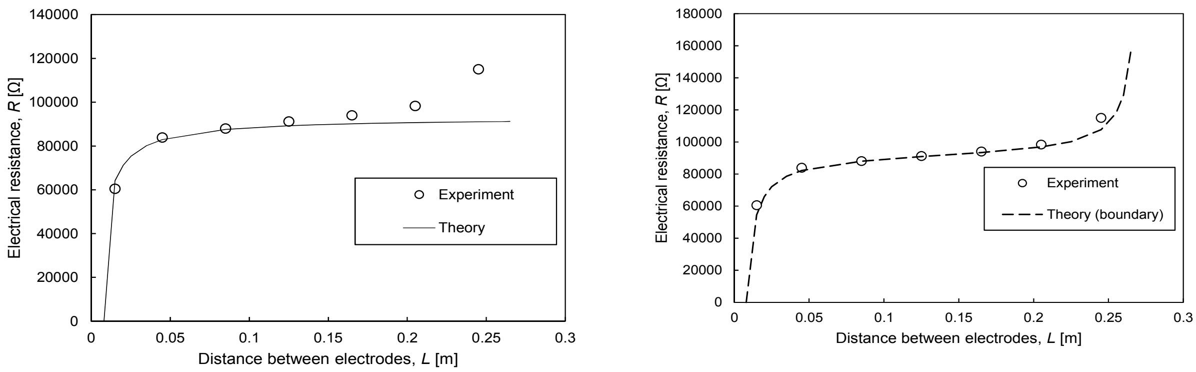
$$R = \frac{r}{N}\left|x_1 - x_2\right| + \frac{r}{M}\left|y_1 - y_2\right| + \frac{2r}{MN}\sum_{m=1}^{M-1}\sum_{n=1}^{N-1}\frac{\left[\begin{array}{l}\cos\left(x_1+0.5\right)\frac{m\pi}{M}\cos\left(y_1+0.5\right)\frac{n\pi}{N}\\ -\cos\left(x_2+0.5\right)\frac{m\pi}{M}\cos\left(y_2+0.5\right)\frac{n\pi}{N}\end{array}\right]^2}{2-\cos\frac{m\pi}{M}-\cos\left(x_1+0.5\right)\frac{n\pi}{N}} \tag{3}$$

where *r* is the electrical resistance of the each resistor, *M* and *N* is the number of the resistors in each directions, x_1, y_1, x_2, y_2 are the *x* and *y* location of two points.

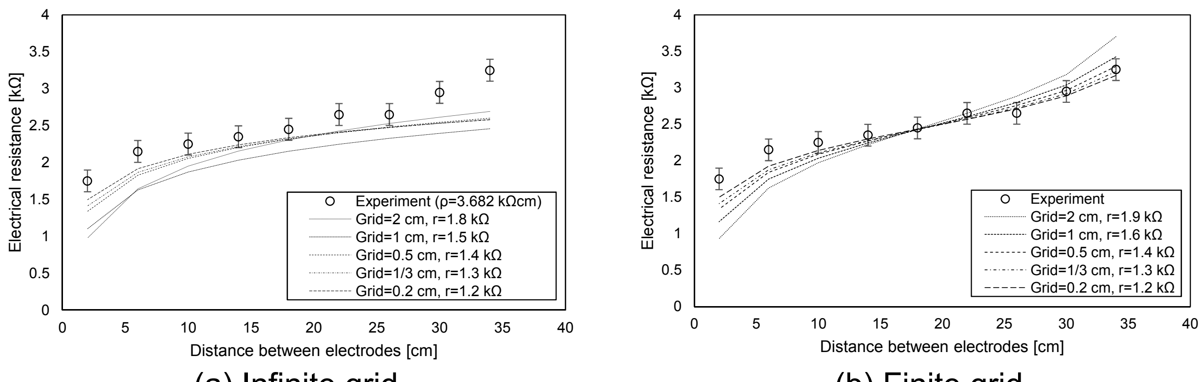
4. EXPERIMENTAL TESTS

Experimental tests were conducted to verify the above equations with brine which has a constant electrical resistivity value. Experimental tests for the image method was conducted with 27 cm container and the brine resistivity was 1.454 kΩ-cm. Experimental tests for the resistor grid method was conducted with 38 cm container and the brine resistivity was 3.682 kΩ-cm.

The results in Fig. 3 and 4 shows that the image method and the resistor grid method can fix the boundary effect during the measurement of the electrical resistance.



(a) No image electrode (b) Image electrode
Fig. 3 Electrical resistance from the image method



(a) Infinite grid (b) Finite grid
Fig. 4 Electrical resistance from the resistor grid method

5. CONCLUSIONS

The evaluation of the boundary effect is one of the key parameter in laboratory scale tests especially in the measurement of the electrical resistance. Image method and resistor grid method can help to evaluate the boundary condition.

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