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Applied of Electrical Resistivity Method on Concrete Structures

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SUMMARY

Nowadays, non-destructive testing (NDT) methods such as electrical resistivity method plays important role in the evaluation and testing of civil engineering structures. The aim of the study is to give basic principles of electrical resistivity method and their limitations in the structural evaluation programme and provide information about agreed standards that obtained various concrete materials. For this reason, in this study, electrical resistivity method was used to determine that the quality of the concrete and reinforcement within the concrete situation and position. The five different cylindrical concrete models with the same dimension (15x30 cm) are prepared for this study. Iron pieces, sponges and rebar in different size are put into the concrete to determine the resistivity responses of the models. After that, the concrete models are incubated approximately 21 days in a tank filled with water for gaining strength. The resistivity measurements are carried out on each cylinder model in three profiles. On the cylinder models, Wenner and Dipole-Dipole arrays used to obtain data, and interpreted using 2D inversion programme (DC2dTree, developed by Thomas Günther).

Introduction

Concrete is the most important material for the production of present-day structure. In our environment, many of structures such as buildings, roads, bridges, dams, power plants, retaining walls, water tanks, ports, airports etc. are made of concrete. Due to the fact that the chemical and physical processes taken place in concrete may give rise to damage in concrete material such as porosity and corrosion of rebar. Therefore, the concrete material can be damaged and lost its strength. It is important that the concrete should certainly be the most resistance to environmental effects during the service life of reinforced concrete buildings. After the concrete is hardened, many of experiments and tests are applied on this material whether it is suitable and resistance for construction.
For these tests and experiments, non-destructive methods such as electrical resistivity, ultrasonic velocity, acoustic method, GPR etc are used. One of the non-destructive method is electrical resistivity has widely been used in testing of concrete material (Carino, N.J., 1999). Electrical resistivity method is used to solve many problems such as revealing the fractured and layered structures (Lataste, J.F., Breyse, D., Sırıeıx, C., Frappa, M. and Bournazel, J.P., 2002), in determining concrete or reinforced concrete structures occurred erosion (Buyle-Bodin, F., Ammouche, A. and Garciaz, J.L., 2003), cracking and layering decays that is used to in highway and housing construction (Chouteau, M. and Beaulieu, S., 2003), in determining the characteristics of the fractures occurred in concrete structures (Lataste, J.F., Breyse, D., Sırıeıx and Abraham. O., 2003) and imaging of the spread of water in concrete samples (Buettner, M., Daily, W. and Ramirez, A., 1996). Consequently, in this study, electrical resistivity method is applied on different concrete core samples so as to determine the strength of these samples and the expected situation of rebar in concrete samples.

Method and Data

The electrical resistivity method involves measuring the apparent resistivity of soils and rock as a function of depth or position. During a resistivity survey, current is injected into the earth through a pair of current electrodes, and the potential difference is measured between a pair of potential electrodes (Figure 1). The current and potential electrodes are generally arranged in a linear array. Common arrays include the Dipole-Dipole array, Pole-Pole array, Schlumberger array, and Wenner array. The apparent resistivity is the bulk average resistivity of all soils and rock influencing the current. It is calculated by dividing the measured potential difference by the input current and multiplying by a geometric factor specific to the array used and electrode spacing. In a resistivity sounding, the distance between the current electrodes and the potential electrodes is systematically increased, thereby yielding information on subsurface resistivity from successively greater depths.

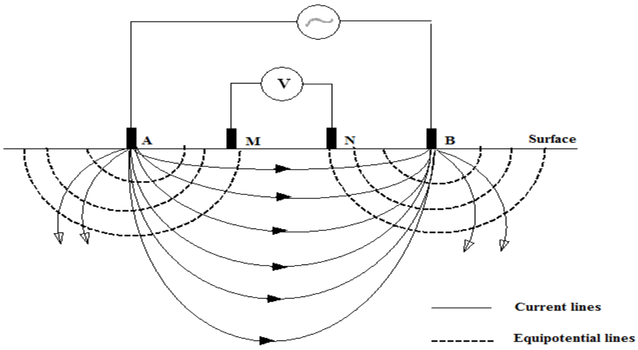

Figure 1 *The basic principle of electrical resistivity method, current (A, B) and potential (M, N) with the current electrodes and the distribution of equipotential lines.*

$$\rho_a = K \cdot \frac{\Delta V}{I}$$

Where K is geometric factor, ΔV is potential difference (volt) and I is the current (amp).

The five different cylindrical models with the same dimension (15x30 cm) are prepared for this study. Iron pieces, sponges and rebar in different size are put into the concrete to determine the resistivity responses of the models. These models and profiles of the measurement, shown in Figure 2., are as follows; the 6-iron pieces with the dimension of 1x9 cm is placed inside first model, the 6-sponge pieces with the dimension of 1x4x9 cm is placed inside second model, the third model is empty with no rebar and sponge, the iron rebar with the dimension of 1x27 cm is placed inside fourth model, and the sponge bar with the dimension of 1x4x30 cm is placed inside last model. After that, the concrete models are incubated approximately 21 days in a tank filled with water for gaining strength. The resistivity measurements are carried out on each cylinder model in three profiles. The distance between profiles is 7.5cm and the distance between electrodes 3cm. In order to avoid the side effects occurred on the measurements, no measurement is carried out on the upper and lower portion of the cylinders of 7.5cm. On the models used in this study, resistivity measurements are acquired using Wenner and Dipole-Dipole electrode arrays.

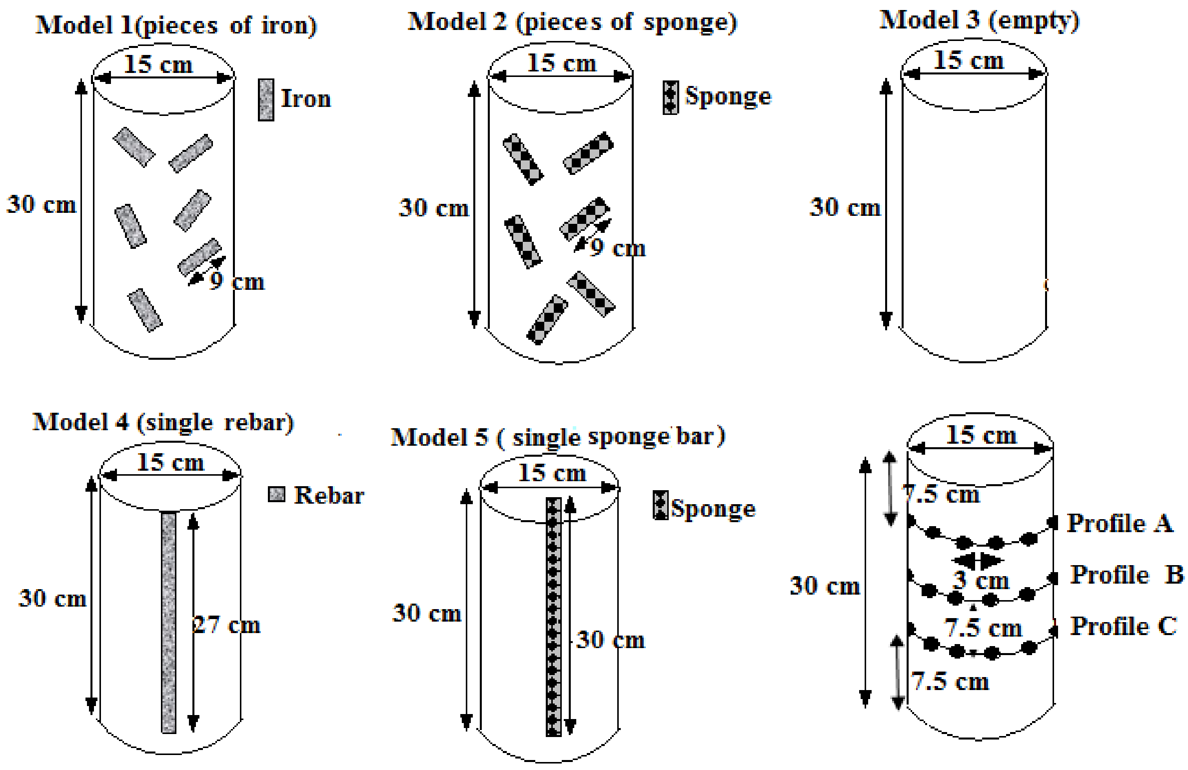

Figure 2 *Schematic representation of cylindrical models used in lab studies and profiles of the measurement.*

Conclusions

By using Wenner and Dipole-Dipole electrode array method, some of the properties are distinguished in the first model. The small red-dashed circles in the inversion cross-section correspond to low impedance areas where apparent resistivity values are 45 Ohm.m using Wenner array and 25 Ohm.m using Dipole-Dipole array (Figure 3a). In second model, it is obtained that apparent resistivity value is about 30 Ohm.m using Dipole-Dipole array whilst the edges of this model displays a highly resistant behavior; the apparent resistivity value is close to 100 Ohm.m (Figure 3c). If one looks at the cross-section obtained from inversion of resistivity data of unequipped model, it is clearly shown that the middle part of the model is highly conductive and is not fully dry because of the humidity at the laboratory. Apparent resistivity values obtained this model are 20 Ohm.m for the middle part of the structure and 80 Ohm.m for edges of the third model (Figure 3e). In fourth model, equipped with one iron bar, the location of the iron bar is clearly determined using Wenner array and apparent resistivity value is 50 Ohm.m (Figure 3b). The last model is similar to the fourth one. But, the sponge bar is used instead of iron bar in this model. It is determined that the middle part of the sponge bar model is conductive using Dipole-Dipole array. The apparent resistivity value is obtained 30 Ohm.m for the region including sponge bar and its close area (Figure 3d). All of measurement results are shown in Figure 3 (Altundas, S., 2010).

In this study, it is learned that the electrical resistivity method is very useful for determination of the location of reinforcements in concrete.

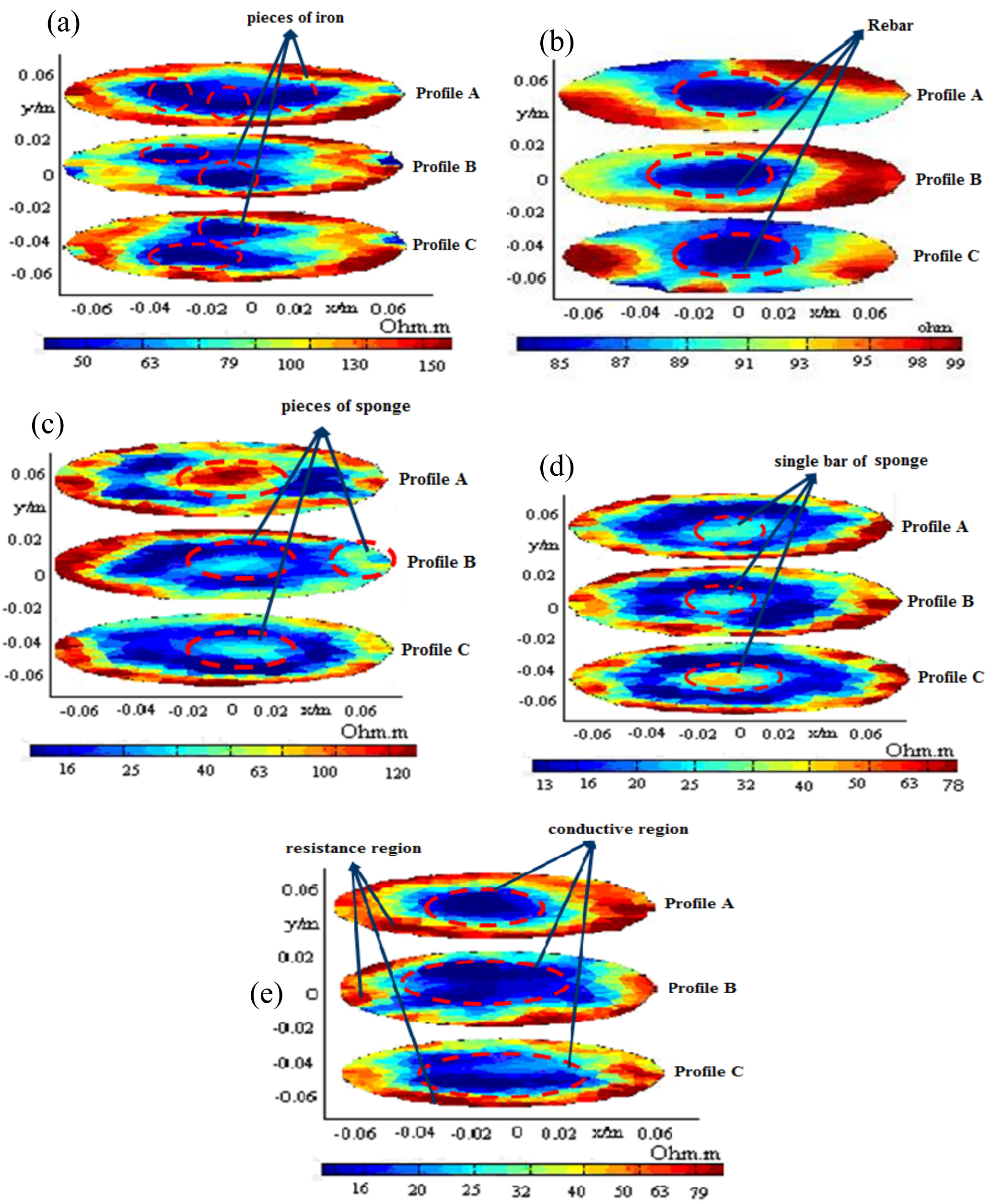

Figure 3 *Two-dimensional inverse solution of apparent resistivity data taken with Wenner and Dipole-Dipole arrays and the possible structures (red dashed circles). a) Model 1 (by the Wenner array) b) Model 4 (by the Wenner array) c) Model 2 (by the Dipole-Dipole array) d) Model 5 (by the Dipole-Dipole array) e) Model 3(by the Wenner array).*

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