World Academy of Science, Engineering and Technology
International Journal of Electrical and Computer Engineering
Vol:4, No:12, 2010

Analysis of Resistance Characteristics of Conductive Concrete Using Press-Electrode Method

Chun-Yao Lee and Siang-Ren Wang

***Abstract*—**This paper aims to discuss the influence of resistance characteristic on the high conductive concrete considering the changes of voltage and environment. The high conductive concrete with appropriate proportion is produced to the press-electrode method. The curve of resistivity with the changes of voltage and environment is plotted and the changes of resistivity are explored.

***Keywords*—**conductive concrete, resistivity.

I. INTRODUCTION

WITH unique physical property, concrete is widely used around the world. To ensure the road smooth, transportation safety, and the airports operation efficiency, the conductive concrete is commonly to be applied to pave on the roadway. The conductive concrete applied to the road surface with snow is particularly effective, since the road surface can be cleaned rapidly and efficiently. For road maintenance in the area with snow in winter, this project becomes significant [1]-[3]. In addition, for a grounding system, the soil resistivity is the critical concern for a grounding system. The conductive concrete with low resistivity characteristics can be applied to grounding system. In the case of grounding resistance of the transmission tower, if the concrete with conductive property combined with the original grounding grid is applied as the foundation of tower, the grounding resistance of the tower would be greatly reduced. Power from lightning can be dissipated to the earth rapidly, and the transmission reliability can be enhanced. For this reason, many scholars have devoted to the studies related to conductive concrete in recent years [4], [5]. The conductive concrete with conductive and magnetic capacity applied to grounding system would moderately reduce the damage caused by lightning and surge. Therefore, this paper aims to study the resistance characteristics of the conductive concrete using press-electrode method and discusses the influences of voltage and environment corresponding to the resistance characteristics of the high conductive concrete.

This work was supported in part by the National Science Council of Republic of China under Contract NSC 99-2632-E-033-001-MY3.

C.-Y. Lee and S.-R. Wang are with the Department of Electrical Engineering, Chung Yuan Christian University, Taoyuan County, Taiwan, 32023. (Phone: +886-3-265-4827; e-mail: chun-yao@ieee.org).

II. CONDUCTIVE CONCRETE AND MODELS

A. Introduction of conductive concrete

The conductive concrete is mixed with a certain amount of conductive material in the cement. Some part of the aggregate in the concrete is replaced by adding metal fibers and metal substances. The conductive concrete known as a compound concrete for special purpose not only maintains its basic mechanical property, but also makes it constitute a conductive network. With the same function as the resistance reducing agent with a lower resistivity, the conductive concrete is particularly employed to the reinforced concrete and road surface. Moreover, the conductive capacity of conductive concrete is different according to the conductive materials and doping concentration. In this paper, materials, proportion and production procedures applied to the conductive concrete is adopted from the reference [5]. The main concrete materials are cement, coarse aggregate, and fine aggregate, and the proportions for each material are 20%-30%, 15%-20%, and 15%-20%, respectively. The conductive material (30%) is further divided to steel fiber (5%), and steel grit (25%). The value of water-cement ratio is between 0.3 and 0.4 approximately. The detailed specification is shown in Table I.

TABLE I
MATERIAL AND PROPORTION OF THE CONDUCTIVE CONCRETE

Material	Proportion	Annotation
Cement	25%	The cement of type I
Coarse aggregates	20%	Maximum diameter is 30mm
Fine aggregates	15%	Maximum diameter is 2mm
Steel fiber	5%	Maximum length is 40mm
Steel grit	25%	Maximum diameter is 1.42mm
Water-cement ratio	0.4	The weight ratio of water and cement
※ The proportion of water is about 15%		

B. Models

The press-electrode method is applied to measure the resistivity of conductive concrete in this paper. Then, the resistivity related to time, temperature and voltage are obtained. The measurement method is depicted as follow.

The press-electrode method is a simple measurement adopted from the concept in reference [6]. The conductive concrete is regarded as a resistance. The specimen of the conductive concrete shares a pair of electrodes for measuring voltage and current, as shown in Fig. 1. This method makes use of adjustable frame to press the electrode and the conductive concrete, that is, this method makes the electrode and the conductive concrete close together. The selected electrode material is made of copper foil and its size should be the same with the cross-sectional area of conductive concrete. Meanwhile, two electrode sides are connected to two wires in

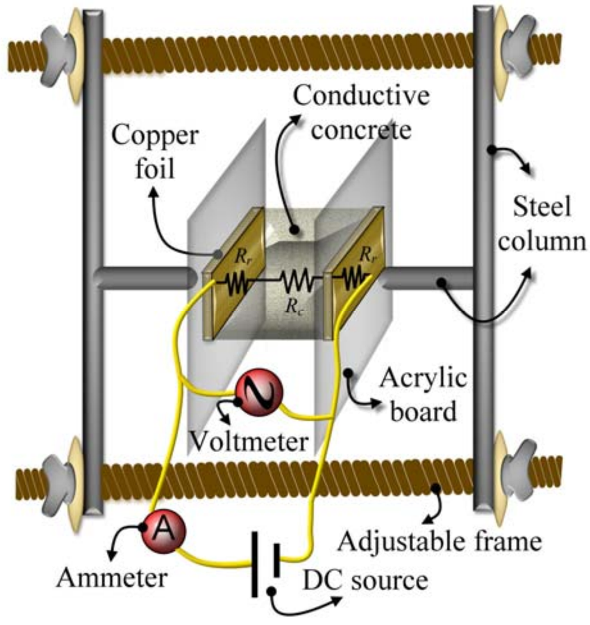

Fig. 1. Structure of the press-electrode method.

which the wire is linked to an ammeter and the DC source is supplied. Consequently, the values of voltage and current are recorded.

C. Formula

Ohm's law is applied to the two methods and the resistance R_c of the conductive concrete between b and c, and the resistivity ρ are obtained, as shown (1) and (2), respectively.

$$2R_r + R_c = \frac{V}{I} \tag{1}$$

$$R = \rho \frac{l}{A} \tag{2}$$

which

R_r : electrode resistance (Ω)

R_c : resistance of the conductive concrete between b and c (Ω)

V : the voltage between b and c (V)

I : the current flowing through b and c

ρ : resistivity of the conductive concrete (Ω·m)

l : the length between b and c (m)

A : contact sectional area between the conductive concrete and electrode (m^2)

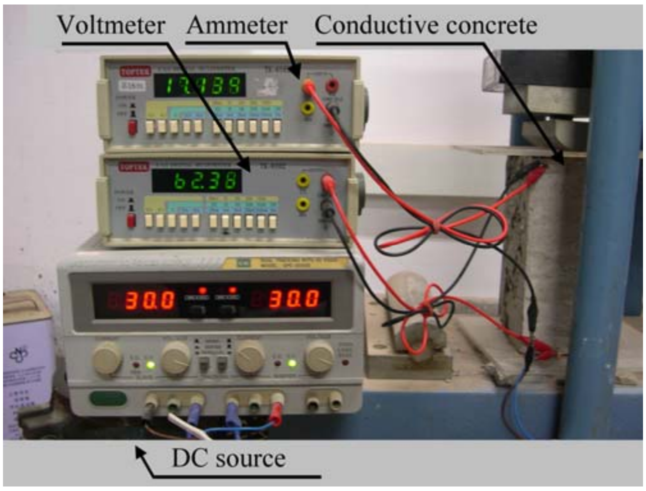

Fig. 2. Measured diagram of the press-electrode method.

III. Practical Model and Measurement

A. The practical models

The press-electrode method is implemented by means of adjustable pressed device. Because the pressed device is iron made equipment, both the ends of the outer electrode covered with acrylic is to avoid electricity from leaking to the equipment. The moderate pressure is taken to press cooper electrode and the conductive concrete. The conductive concrete

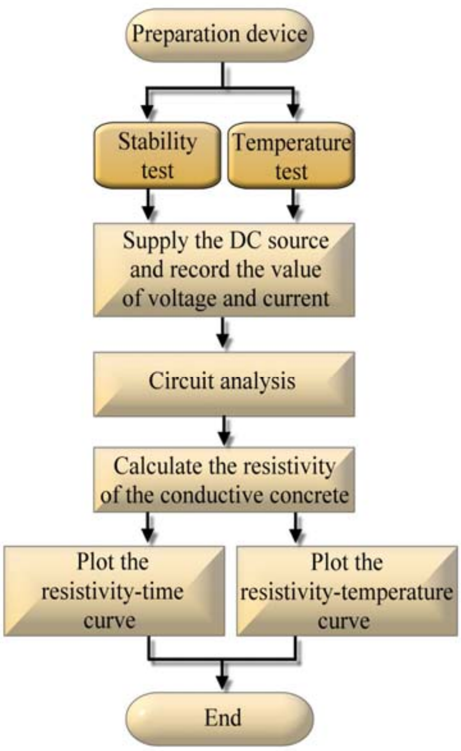

Fig. 3. Flowchart of the resistivity measurement.

with DC source at electrode side is subsequently connected to ammeter and voltmeter. The measurement instruments contain a set of power supply and two sets of meters, as shown in Fig. 2. The voltage and current considering various factors are recorded.

B. Step of the measurement

To measure the effect of time and temperatures using the press-electrode method, a better measurement is chosen when the smaller resistivity without severe change as time varying. Meanwhile, the conductive concrete is placed outside, and the temperature and environmental conditions are recorded. The measurement flowchart is shown in Fig. 3, and the steps are briefly listed below.

a. The equipment is prepared for press-electrode method.
b. The voltage and current of the conductive concrete are measured using the proposed methods, and the resistivity is calculated according to Ohm's law.
c. The stability test is recorded once per 60 seconds.
d. The conductive concrete is placed outdoors and it is measured at different temperature and climate conditions.
e. The resistivity-time and resistivity-temperature curves are drawn.
f. The results of the measurement method is discussed.

IV. The Data and the Measured Results

For a better understanding of the influence on the resistivity of the high conductive concrete, temperature and humidity are considered, and the stability of the high conductive concrete is tested using the press-electrode method. The results have shown that by using the press-electrode method, more influencing factors are comprised and the error of the resistivity is relatively high. However, using the method, the generated polarization in process of connecting voltage source cannot be avoided and contact resistance between electrode and the conductive concrete is not reduced. Therefore, the resistivity measurement of the conductive concrete at different voltage cannot obtained through the press-electrode method.

A. Time

The conductive concrete is not a general dry solid material. When connected to voltage source, the conductive particles inside of the conductive concrete are affected. This phenomenon displays the unstable data obtained from voltmeter and ammeter and results in measurement error every time. To understand the stability and accuracy of the press-electrode method in the process of measurement, the stability of conductive concrete is firstly tested. The data in terms of the press-electrode method is recorded once 60 seconds, and 10 data are recorded in one day. Finally, these data are applied to calculate the resistivity in the unit of (Ω·m). The result of the 7-day measurement is shown in Table. II.

B. Temperature and moisture of the environment

The conductive concrete is placed outdoors. To observe the influence of conductive concrete on resistivity in different environments, including dry and wet conditions, the recorded data comprising the measurement values in sunny and rainy days are compared. The measurement data using press-electrode method are shown in Table III. Besides, these data is plotted to observe the curves related to resistivity, and outdoor temperature and climate as well, as shown in Fig. 4.

TABLE II
DATA OF THE RESISTIVITY IN STABLE TEST

Date	Measurement	2 min(s)	4 min(s)	6 min(s)	8 min(s)
Day 1	Press-electrode	65.84	65.41	65.66	65.45
Day 2	Press-electrode	76.76	76.84	77.07	77.41
Day 3	Press-electrode	86.28	86.31	86.36	86.91
Day 4	Press-electrode	94.45	94.63	94.69	94.92
Day 5	Press-electrode	102.34	102.61	102.31	102.71
Day 6	Press-electrode	113.49	112.95	113.75	112.57
Day 7	Press-electrode	122.66	122.78	121.66	121.13

TABLE III
DATA OF THE RESISTIVITY IN ENVIRONMENT TEST
(PRESS-ELECTRODE METHOD)

Drying		Wetting	
Temperature (℃)	Resistivity (Ω·m)	Temperature (℃)	Resistivity (Ω·m)
16	65.83	10	49.38
17	65.79	11	48.56
18	65.62	12	48.31
19	65.56	13	48.02
21	65.41	14	47.79
23	65.28	15	47.53
24	65.15	16	47.13

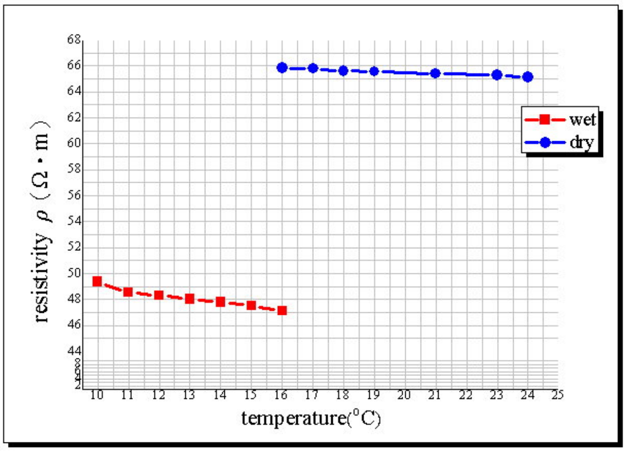

Fig. 4. Relation curve of resistivity and temperature in press-electrode method.

V. Analysis and Discussion of the Results

The resistivity of the high conductive concrete using press-electrode method is investigated. The resistance characteristics are observed. Since the pore solution of the conductive concrete is gradually decreased in the dry environment, and steel fiber and steel grit would go rust slightly in the alkaline environment of cement, the conductive capacity is gradually decreased. For this, the two factors directly influence the current and make the resistivity increase. The result of the stability has shown that resistivity of the conductive concrete significantly increases and the resistivity curve also rises by days, as shown in Table II. Practically, the contact resistance is the main problem that causes to error for the press-electrode method. If there is any gap between the electrode and the concrete, the contact area is decreased, and the current is relatively decreased. By calculation, the contact area is a constant, and hence the resistivity is significantly increased. Moreover, the polarization is generated in the process of power supply for the press-electrode method. The anions are gathered at positive pole and cations are gathered at negative pole. The ions are deposited around the electrode, referred as the polarization response of the concrete. This phenomenon leads to back EMF and makes the measured current value smaller than actual value. As the ions are gradually accumulated around the electrode, the polarization is getting obvious until the polarization is balanced.

On the other hand, the conductive concrete with pore solution is capable of either absorbing or evaporating water depending on the moisture change, for this reason, the resistivity of the conductive concrete is varied as the environment change. By observing Fig. 4, when the conductive concrete is placed outdoors, the resistivity of the conductive concrete is influenced by temperature and humidity. The higher the temperature and humidity are, the lower resistivity is, as shown in Table III. Considering the influencing factor of the internal water, after the concrete hydration, many ionic substances, electrolytes, is dissolved in the water and interconnected by capillary. Therefore, as the water increases, the conductive concrete of conductivity is increased and the tightness of the concrete structures is maintained. Comparing the factors between temperature and moisture, the resistivity of conductive concrete is evidently to be affected by water content. In this way, the warm and humid environment results in a lower resistivity for conductive concrete.

VI. Conclusion

The resistivity of the high conductive concrete is computed in this paper using Ohm's law, and the press-electrode method is applied to measure and record in different conditions, including time, temperature and voltage. The results have shown that either the higher temperature or the higher humidity results in a smaller the resistivity. In addition, the voltage change also affects internal temperature and the structure of the conductive concrete. The greater the voltage is, the smaller the resistivity is. In sum, the resistivity of the high conductive concrete is not a constant value. The resistivity is not only slightly changed day by day, but also affected by external environment.

Generally, the conductive concrete is widely used for deicing; however, this paper focuses on the application of conductive concrete to grounding system. The important parameter, resistivity, is an indicator in terms of grounding system. The resistance characteristics of the conductive concrete are obtained based on the proposed methods and measured data in this paper. The characteristics of the high conductive concrete corresponding to the grounding standard completely can be applied to grounding effectively.

Acknowledgment

The authors would like to thank Professor Chih-Ju Chou and his research center in Dept. Electrical Engineering of National Taipei University of Technology in providing the suggestions of the research. The authors also would like to thank Professor Ming-Yi Liu, Chung-Min Ho and their Labs. in Chung Yuan Christian University in providing the measurement equipments.

References

[1] C. Y. Tuan, S. A. Yehia, "Implementation of Conductive Concrete Overlay for Bridge Deck Deicing at Roca, Nebraska," *Transportation Research E-Circular*, No. E-C063, Jun. 2004, pp. 363-378.

[2] C. Y. Tuan, "Conductive Concrete for Bridge Deck Deicing and Anti-Icing," *University of Nebraska*, *Lincoln*, Jul. 2004, pp.168.

[3] C. Y. Tuan, "Roca Spur Bridge: The Implementation of an Innovative Deicing Technology," *American Society of Civil Engineers*, Vol. 22, Issue 1, Mar. 2008, pp. 1-15.

[4] Yehia S, Christopher Y T, Ferdon D, eta1. "Conductive concrete overlay for bridge deck deicing: mixture proportioning, optimization, and properties [J]," ACI Materials Journal, 2000, 97(2): pp. 172-181.

[5] Hou Zuo-Fu, Li Zhuo-Qiu, Hu Sheng-Liang, "Resistivity Research on Carbon Fibre Electrically Conductive Concrete for Deicing and Snow Melting," Journal of Yangtze University (*Nat Sci Edit*) Vo1. 2, No. 7, pp. 264-266, Ju1. 2005.

[6] Shen Gang, Dong Faqin, He Dengliang, "Study on Graphite and Steel Fiber Composite Electrically Conductive concrete," *Bulletin of the Chinese Ceramic Society*, No. 6, 2004.

Chun-Yao Lee (SM'04, M'08) received his Ph.D. in electrical engineering from National Taiwan University of Science and Technology in 2007. In 2008, he joined Chung Yuan Christian University as a faculty member. Dr. Lee was a visiting Ph.D. at University of Washington, Seattle, during 2004-05 and worked for engineering division, Taipei Government as distribution system designer during 2001-2008. His research interests include power distribution and filter design. Dr. Lee is a member of the IEEE Taipei Section

Siang-Ren Wang was born in Taiwan in 1986. He received his B.S. degree in electrical engineering from Chung Yuan Christian University in 2008. Mr. Wang will be an electrical engineer in a year in Taiwan.