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Electrical Resistivity of Concrete with Chloride Ions

*In-Seok Yoon[1)]

[1))] *Department of Construction Info. Engineering, Induk University, Seoul 01878, Korea*
[1)] *isyoon@induk.ac.kr*

ABSTRACT

The objective of this work is to investigate the effect of microstructure on the electrical resistivity of concrete. The influence of affecting micro-structural factors such as pore volume, water content, tortuosity in pore on electrical resistivity is examined quantitatively. It is expected that the experiment results and interpretations would be a relevant tools for the evaluation of durability design and calibration factors for the estimation of chloride diffusivity. As a result, variation of electrical resistivity depending on chloride content was low at early time, which became stable without significant variation over time. Such tendency was attributable to chloride absorption and microstructure and microstructure of hardened cement body seemed to have more effect on electrical resistivity than absorption of chloride ion.

1. INTRODUCTION

Electrical resistivity is nondestructive evaluation technology that will not cause any damage to the structure and has many advantages including cost reduction, time reduction, real-time data monitoring and simple method (Gjørv, 2009; Liu et al, 2010). However electrical resistivity measurement has many factors causing data interference. Besides temperature and humidity, environmental factors of concrete are carbonation and chloride content. And chloride content in concrete may have effect on electrical resistivity (Goni and Andrade, 1990). When the current is applied, electric field is dependent on chloride content that has effect on pore water transfer (Millard 1991, 1992) and thus it's necessary to monitor the data on change in electrical resistivity of concrete containing various chloride contents over time.

This paper is intended to evaluate the variation characteristics of electrical resistivity depending on chloride content and water content in concrete. With the concrete with different water-cement ratio, variation of electrical resistivity was monitored over time after mixing chloride ion at different ratios. This study is expected to be used to develop the method to correct the effect depending on chloride content and the method to analyze the electrical resistivity of carbonized concrete.

[1)] Professor

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2. EXPERIMENT DESIGN

2.1 Preparation of samples

A commercial cement, Type I KS L 5201 Ordinary Portland Cement (OPC), was used with a water-cement ratio (w/c) of 0.45, 0.50, and 0.55 as shown in Table 1. For chloride contaminated specimen sodium chloride was mixed with mixing water, 0%, 0.5%, 1.0%, 1.5% and 2.0% by weight of cement. The specimen was submerged in same salt water as sodium chloride-mixed water used when producing initial specimen till measuring. The size of each specimen was determined to be 100 mm (L) × 100 mm (W) × 200 mm (H) such that the spacing of the electrodes was much smaller than the height of the materials. The curing temperature was 20 °C. After 28 days of water curing, three different curing conditions, i.e., 1) air-dry, 2) water, and 3) pre-mixed chloride. Testing with three different curing conditions was intended to investigate the change of electrical resistivity due to water content and the chloride content.

2.2 Measurement of electrical resistivity

It is important to prepare the specimen with the same conditions before testing because the electrical resistivity of concrete is significantly sensitive to both moisture and. Before the electrical resistivity measurements were made, the concrete specimens were preconditioned as follows: 1) water was sprayed on the surfaces of the air-dried specimens and; 2) surface water was removed from the saturated specimens. The four-electrode method, known as the Wenner four-pin method, was developed initially for conducting soil resistivity tests by the U.S. Bureau of Standards.

A four-pin resistivity meter, i.e., a Resipod resistivity meter (Swiss PROCEQ Company), was used to measure the electrical resistivity of concrete specimens. For each specimen, four separate measurements were made on four different surfaces.

Table 1 Proportions for concrete mixture

Air (%)	Slump (cm)	w/c	Unit weight (kg/m^3)			
			Water	Cement	Sand	Gravel
4.5±0.5	15±1	0.45	185	411	706	1001
		0.50		370	720	1021
		0.55		336	732	1038

3. RESULTS AND DISCUSSION

Fig. 1 shows the incline of linear regression analysis equation of the electrical resistivity ratio and chloride content with the concrete without chloride content. The gradient of linear regression analysis equation was low at early time, however, it was constant without significant variation from 50 days. That is, decrease in electrical resistivity depending on chloride content was rather low till 50 days and then continued to rise. After 50 days, trend could not be examined. The electrical resistivity of concrete vs. chloride content was insignificant after 50 days and this was attributable to two reasons. First, C-S-H phase and AFm phase which can react with water soluble chloride to form bound chloride are not well developed(Yoon, 2014). At early stage,