Electrical Characterization of Conductive Concrete Using Graphite

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Conductive Concrete composites

Conductive Concrete = Portland Cement + Aggregate + Moisture

+ Conductive Additives (Graphite)

The distributed filler in the composite form a continuous conductive network which is mostly depend on the degree of dispersion of the additives, the volume fractions of fibers, length of fibers, contact electrical resistivity of the interface between the admixture and the cement matrix
Self-sensing on Compression Side Under Cyclic Loading

(Wang & Chung 2006)

Self-sensing on Tension Side Under Cyclic Loading

Specimen under splitting tensile test

(Toemete & Kocyigit 2013)
Objective

• To characterize the electrical properties of conductive concrete using DC and AC Impedance Spectroscopy under wet and dry condition of the specimens.
AC Impedance Analysis And DC Measurement

Sinusoidal Response in a Linear System

Nyquist Plot of Cement Paste

Bode Plot of Sample B1 (SSD)

Nyquist Plot of Cement Paste

Direct Current Graph

Sinusoidal Response in a Linear System
Why AC Impedance Analysis is needed?

• Conductive concrete is a composite material having complex electrical properties including multiple conduction mechanisms and various circuit elements. The properties of conductive concrete cannot be represented by a single resistivity.

• By using AC (alternating current) in various frequency ranges, AC Impedance Spectroscopy allows to characterize the electrical properties with capacitance, inductance, and resistance.

• As per author knowledge, very few studies have been done to understand the electrical conduction mechanism of conductive concrete using both AC Impedance Spectroscopy and DC Analysis.
Specimen Preparations of Conductive Concrete

Ingredients = Cement + Water + Graphite (3% by volume of Cement Paste)
Test Methods

**Equipment:**
- DC Measurement: Keithley 2400 (C-22)
  - Voltage information: 10 V, 1V, 0.1 V, 0.01V
- AC Measurement: Metrohom Autolab PGSTAT302N
  - Voltage – 0.5 V
  - Frequency Range – 1,000,000 Hz to 1 Hz
  - No of Cycle of Sine Wave - 10
- 2-point sensing method
Bode Plot of Specimen Set A (Both in SSD and Dry)
Nyquist Plot of Specimen Set A (Both in SSD and Dry)

Nyquist Plot of Sample A1 (SSD)

Nyquist Plot of A2 (SSD)

Nyquist Plot of A3 (SSD)

Nyquist Plot of A1 (Dry)

Nyquist Plot of A2 (Dry)

Nyquist Plot of A3 (Dry)
Static Resistivity at 1 V of Specimen Set A (Both SSD and Dry)
Static Resistivity at different Voltage of Specimen Set A (Both SSD and Dry)
Conclusion

• From Bode plot, it is observed that electrical Resistivity decreases with the increase in frequency of Alternating Current. This indicates our specimen is acting like a capacitor which store charges inside it.

• Moisture plays a very important role in electrical resistivity measurement. In wet (SSD) condition, electrical conduction is governed by both quantum tunneling and ionic conduction of OH⁻, which enables the decrease in resistivity. In Dry condition, there is no presence of moisture, conduction only through quantum tunneling governs and hence the electrical resistivity increases. For every test, Dry specimen shows higher resistivity than the wet specimens.

• Graphite modified conductive concrete forms a very complex composite materials and our study indicates that it is difficult to obtain a single value resistance from static measurement using DC.
Reference


Any Questions?