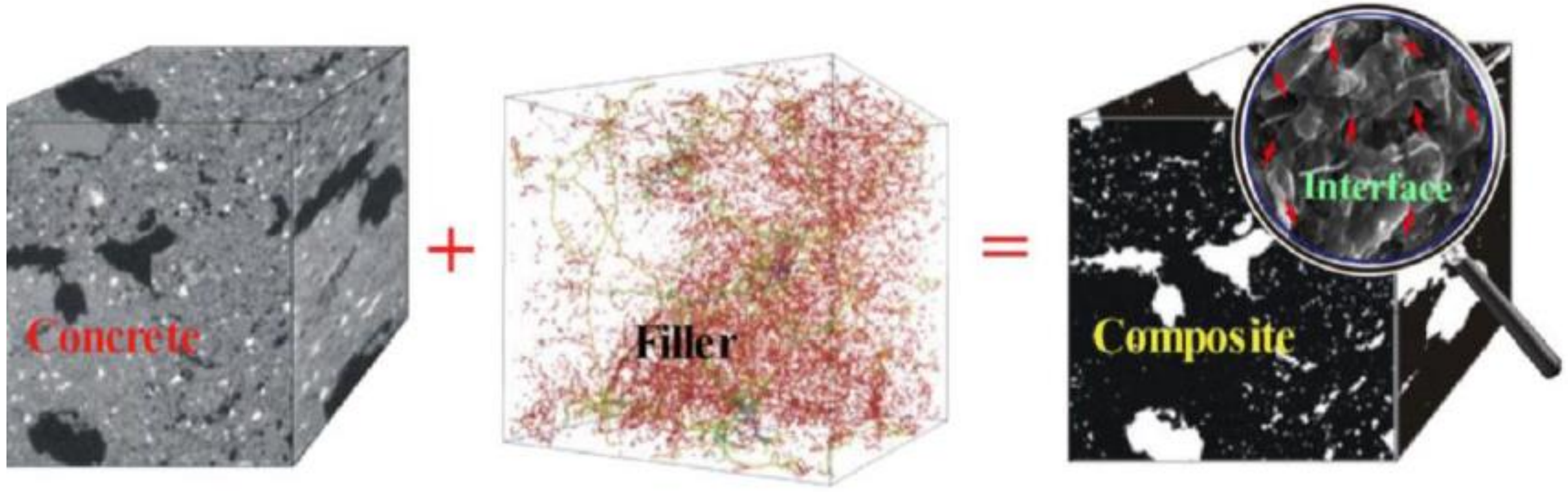
Electrical Characterization of Conductive Concrete Using Graphite

By

K I M Iqbal and Philip Park

Conductive Concrete composites



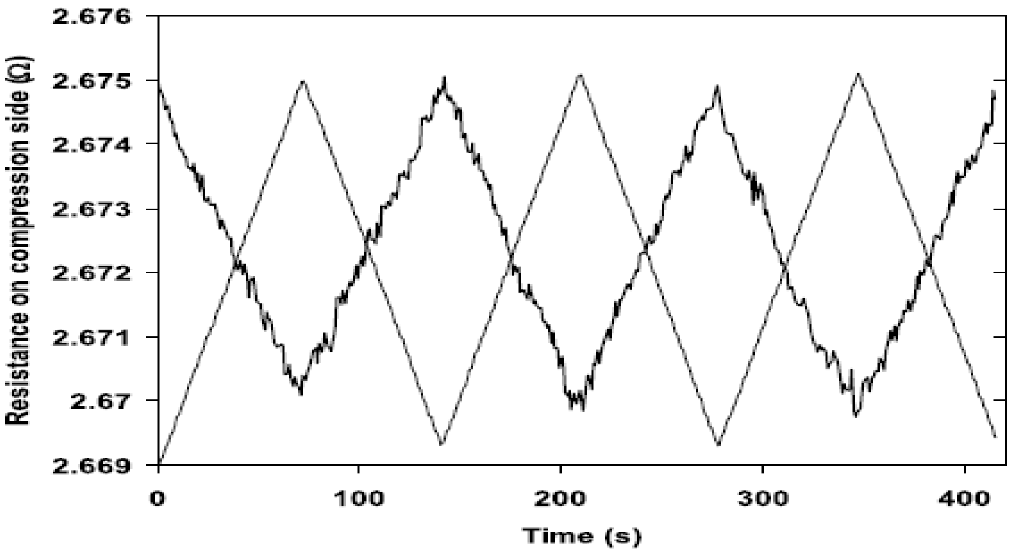
(Han et al. 2015)

Conductive Concrete = Portland Cement + Aggregate + Moisture

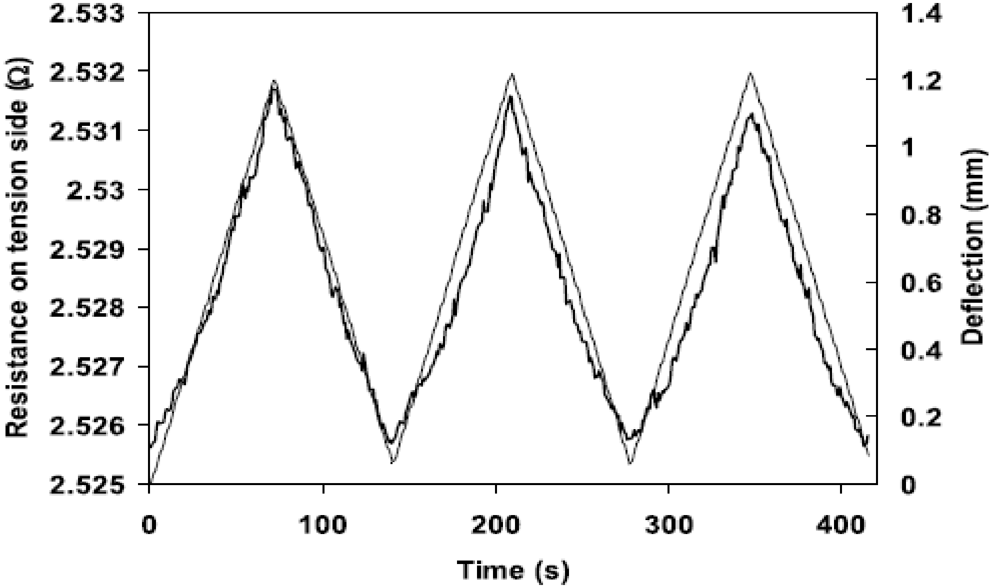
+ Conductive Additives (Graphite)

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

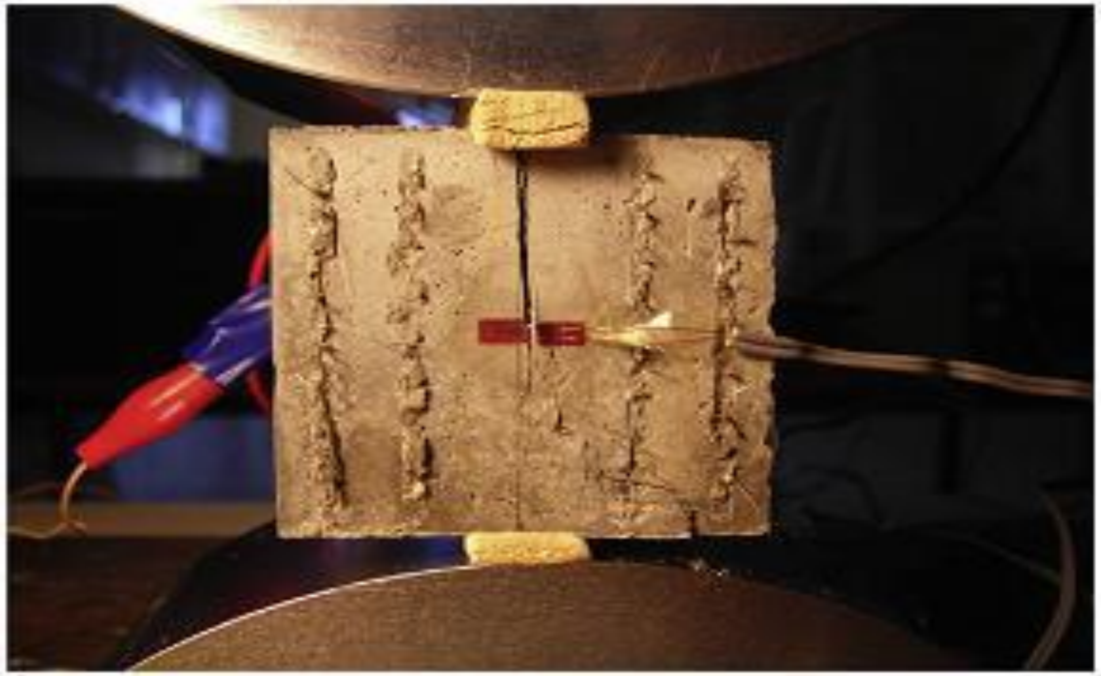
Self-sensing on Compression Side Under Cyclic Loading



Self-sensing on Tension Side Under Cyclic Loading



(Wang & Chung 2006)



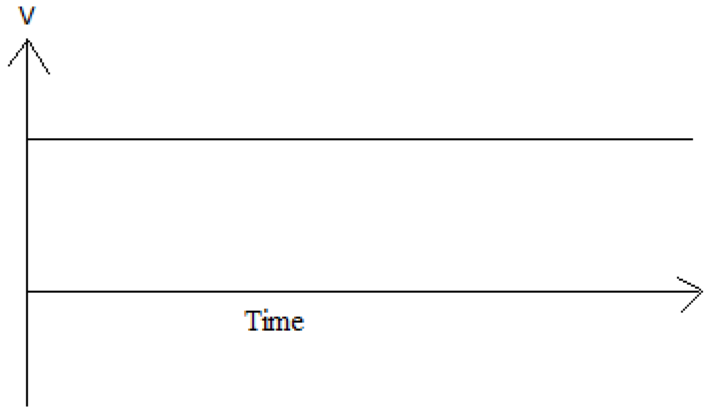
Specimen under splitting tensile test

(Toemete & Kocyigit 2013)

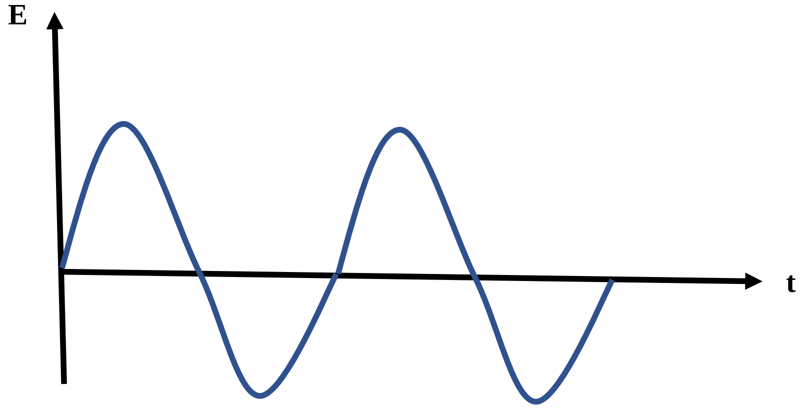
Objective

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

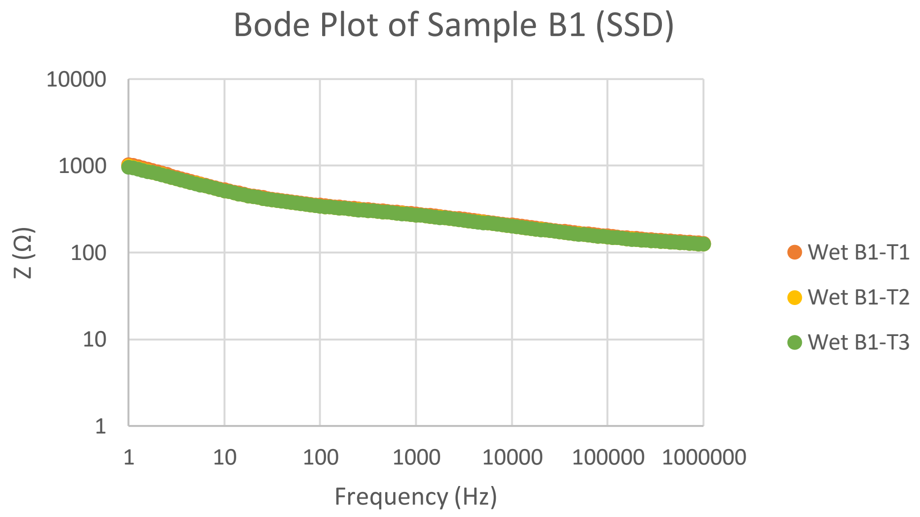
AC Impedance Analysis And DC Measurement

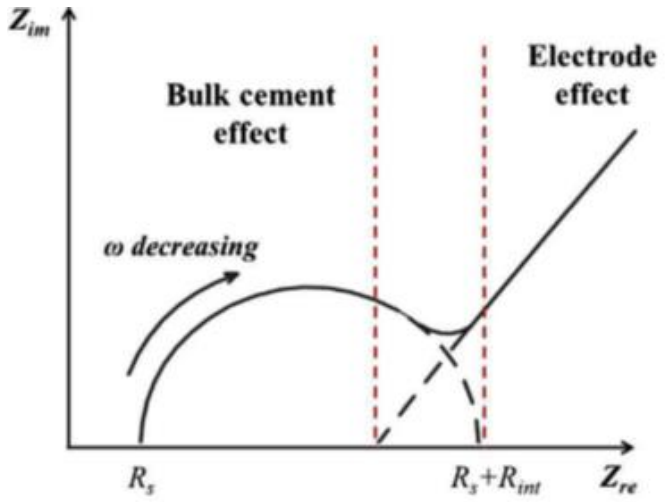


Direct Current Graph



Sinusoidal Response in a Linear System



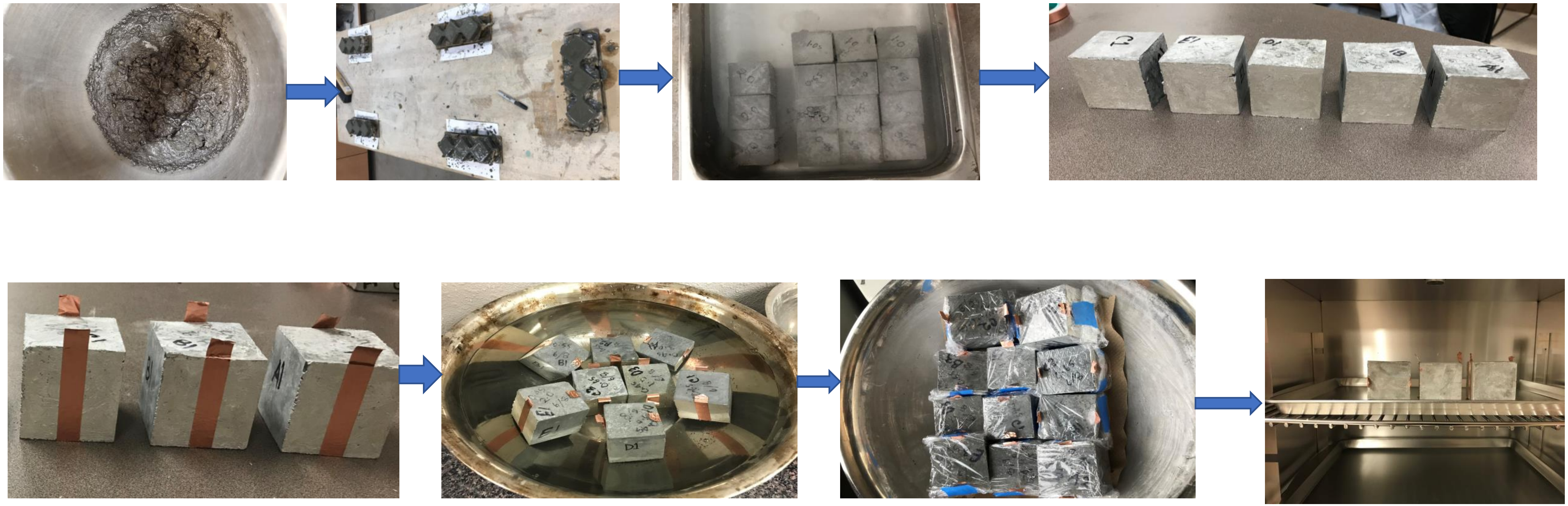


Nyquist Plot of Cement Paste (Hu et al. 2019)

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

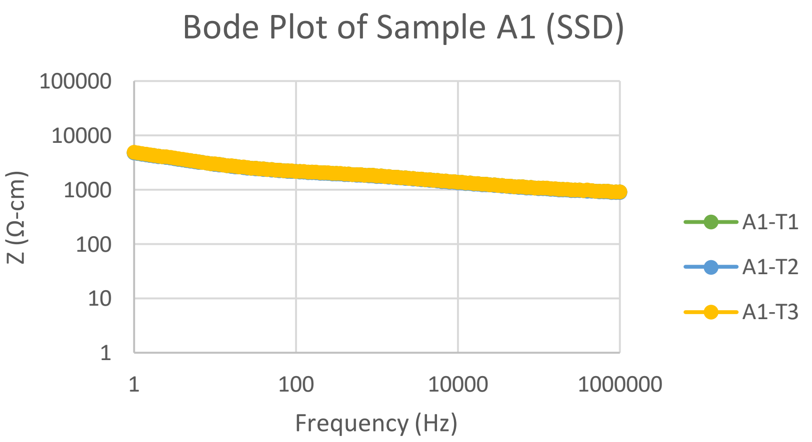


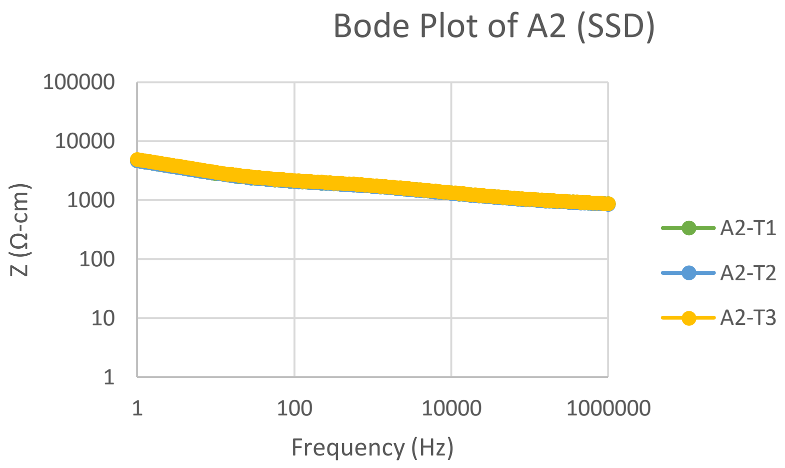
Ingredients = Cement + Water + Graphite (3% by volume of Cement Paste)

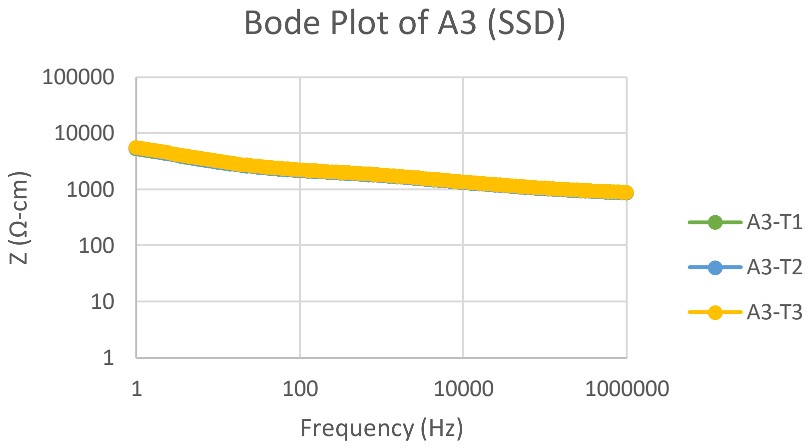
Test Methods

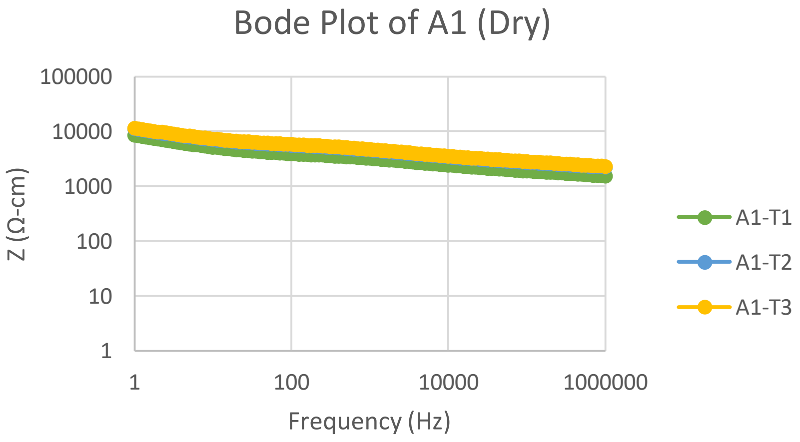
- **Equipment:**
  - DC Measurement: Keithley 2400 (C-22)
    - Voltage information: 10 V, 1V, 0.1 V, 0.01V
  - AC Measurement: Metrohom Autolab PGSTAT302N
    - Voltage – 0.5 V
    - Frequency Range – 1,000,000 Hz to 1 Hz
    - No of Cycle of Sine Wave - 10
  - 2-point sensing method

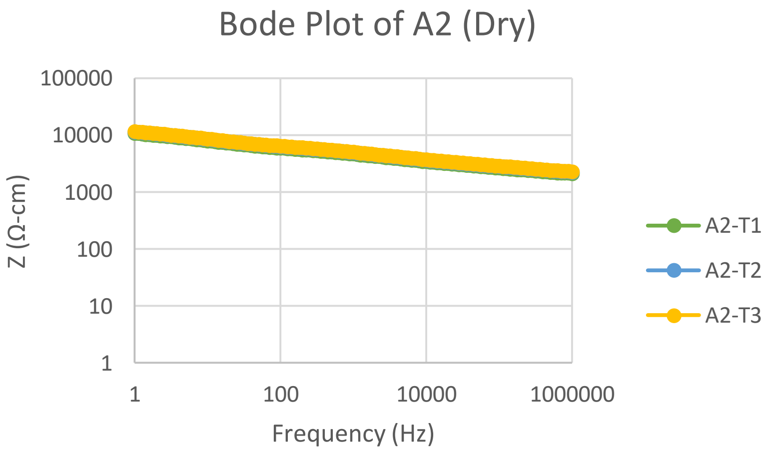
Bode Plot of Specimen Set A (Both in SSD and Dry)

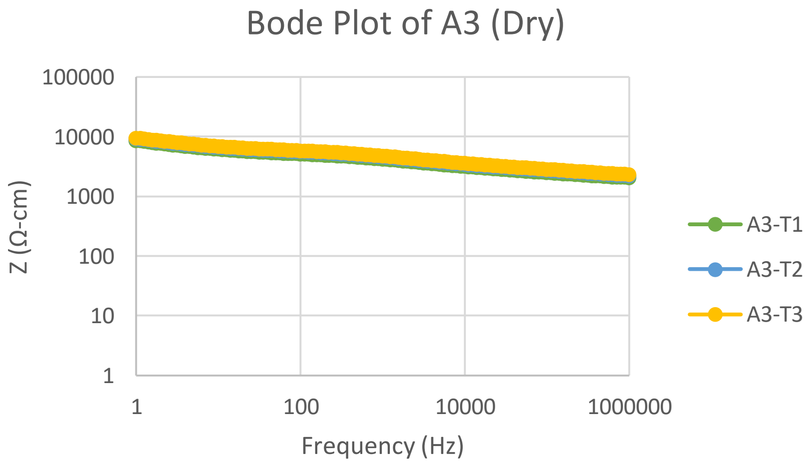




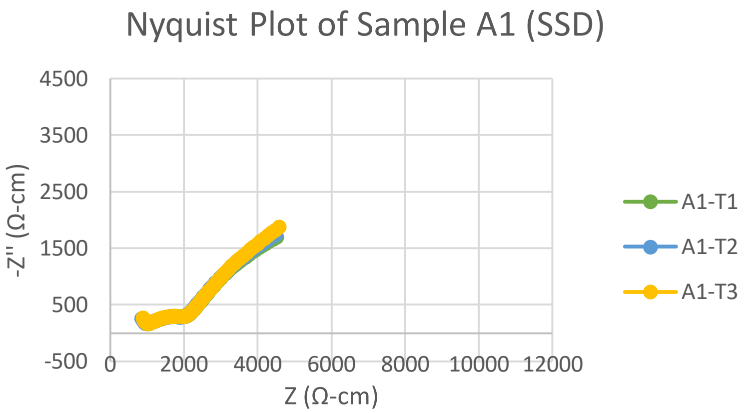


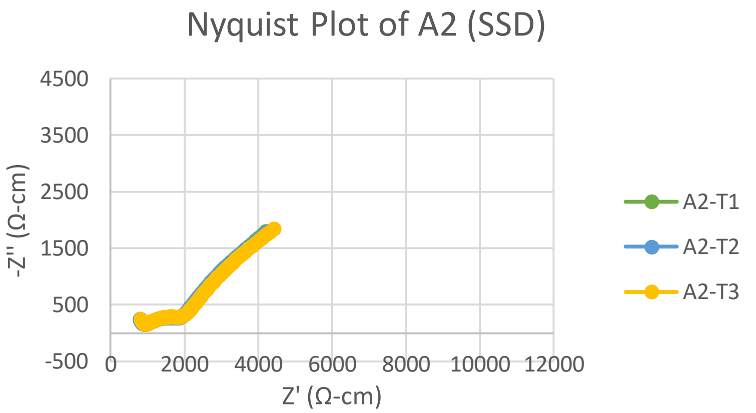


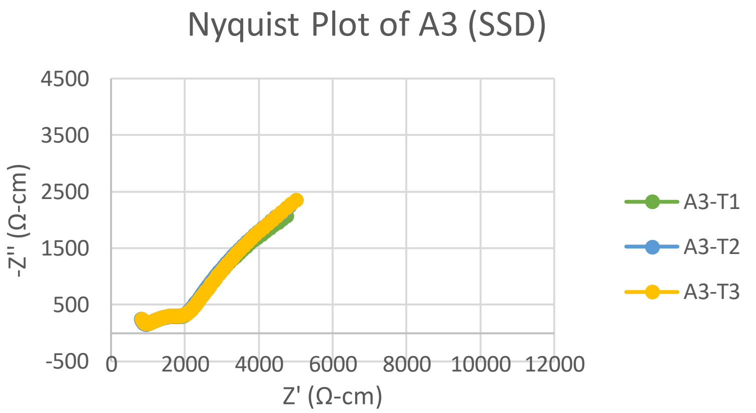


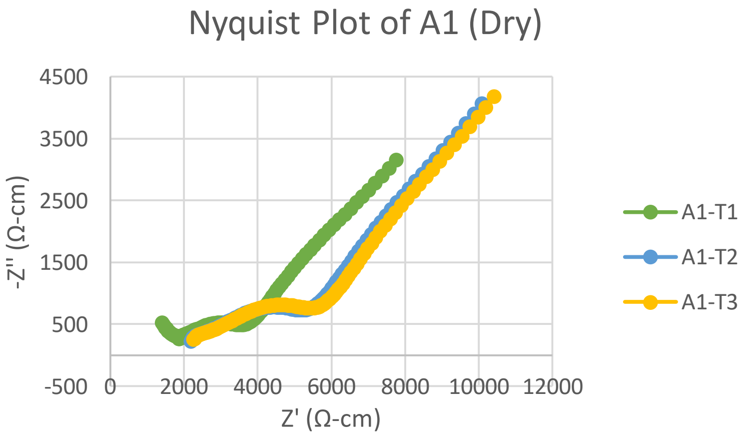


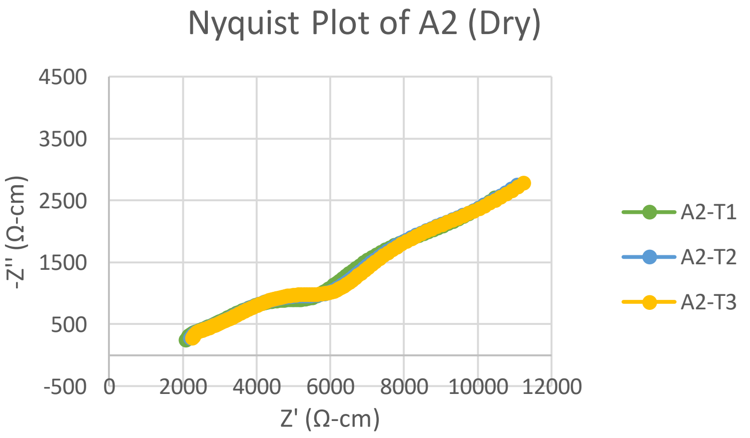
Nyquist Plot of Specimen Set A (Both in SSD and Dry)

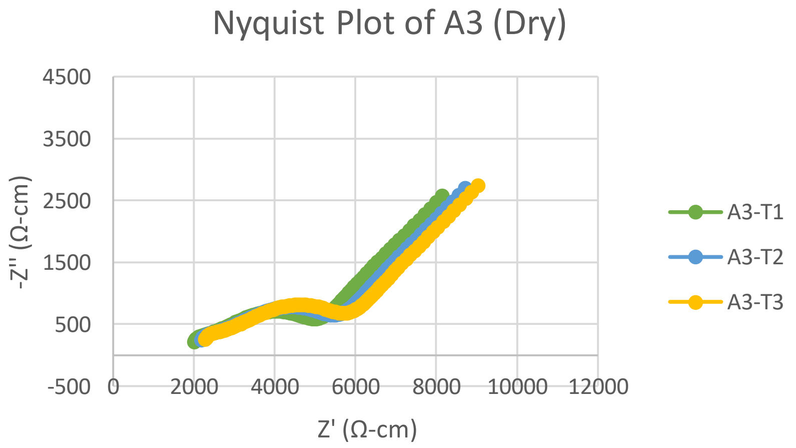




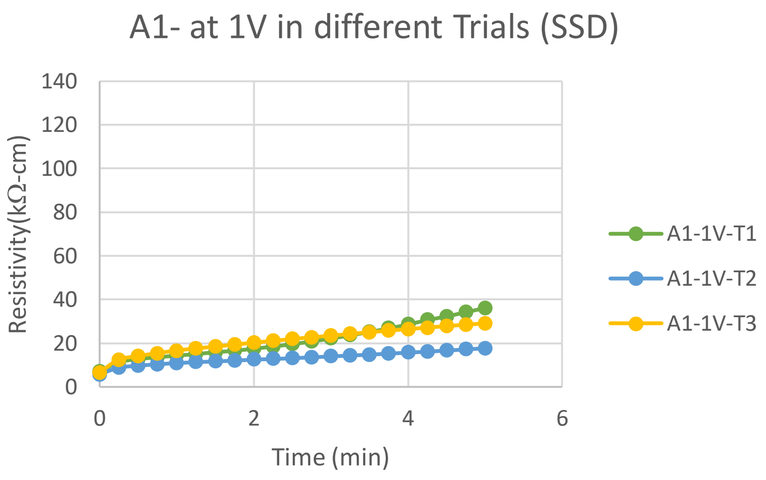


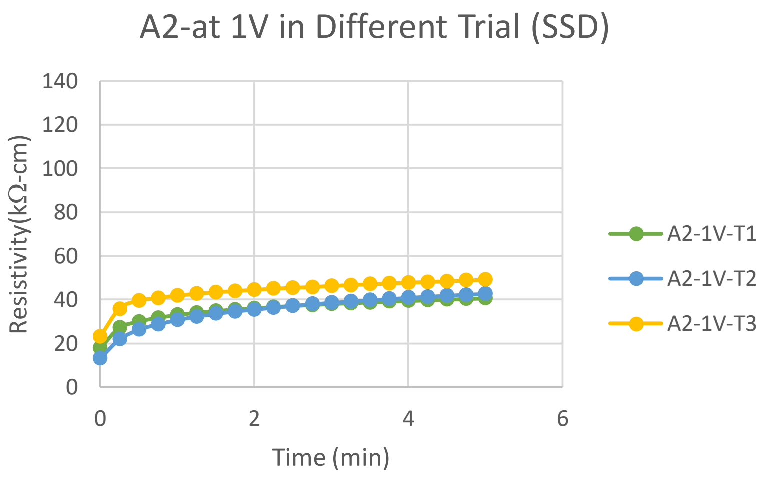


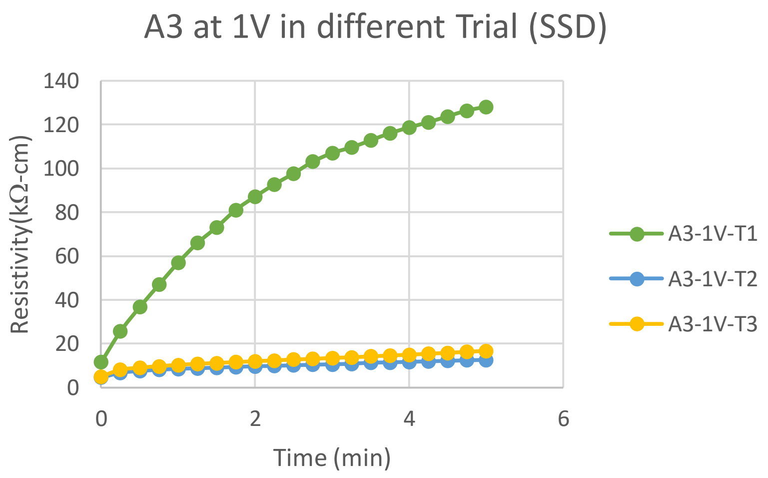


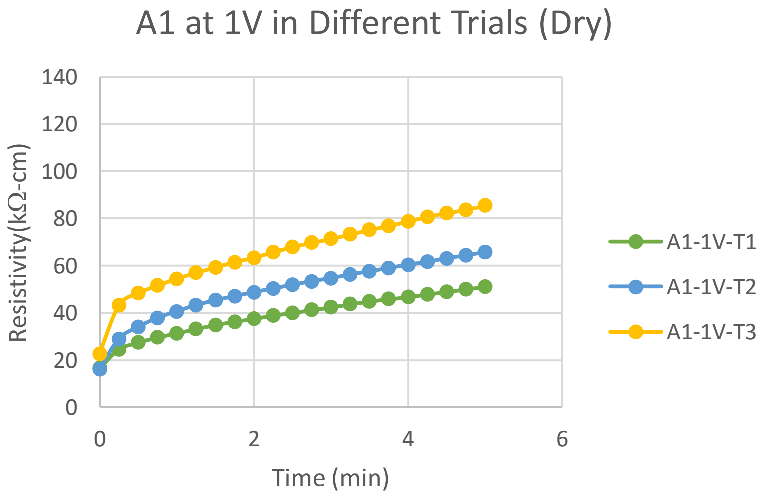


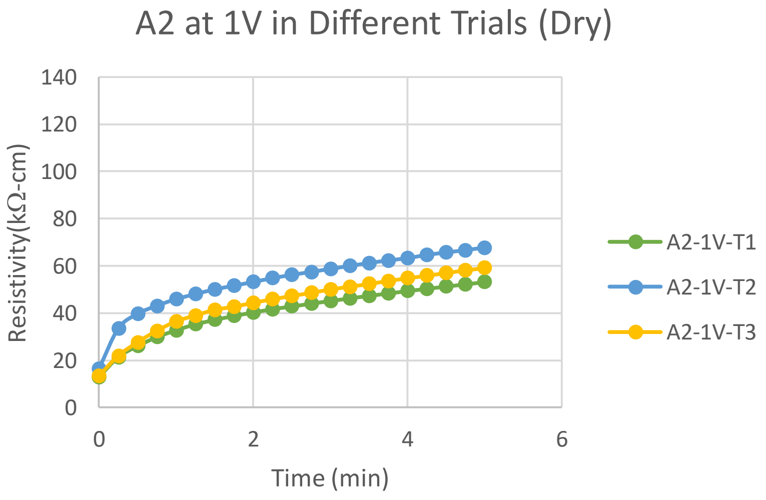
Static Resistivity at 1 V of Specimen Set A (Both SSD and Dry)

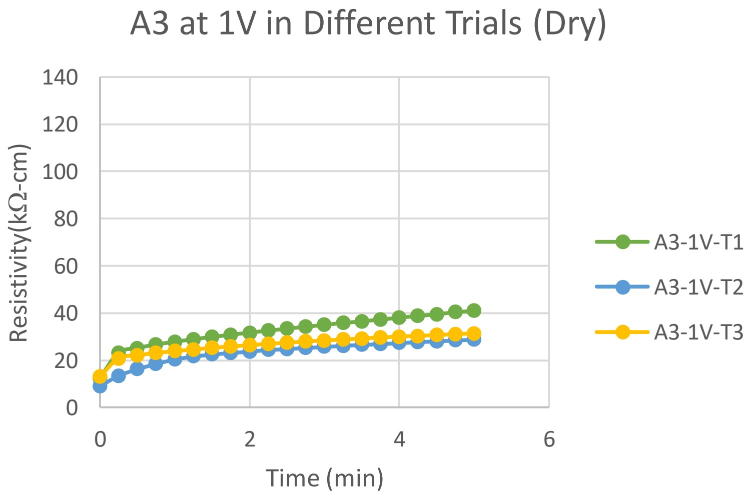




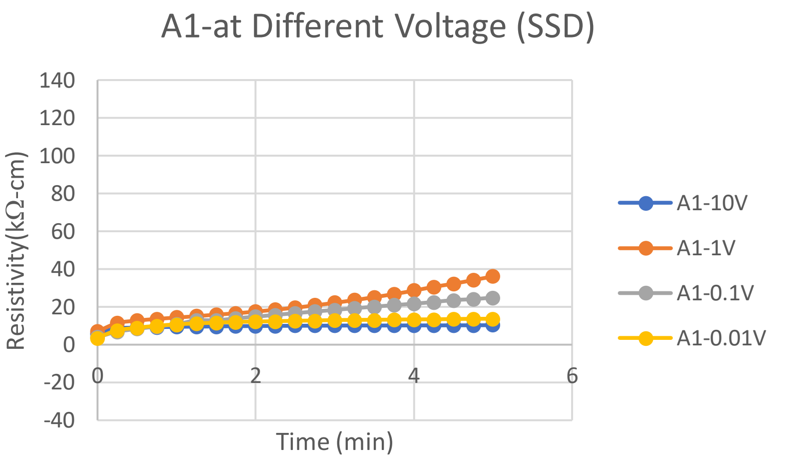


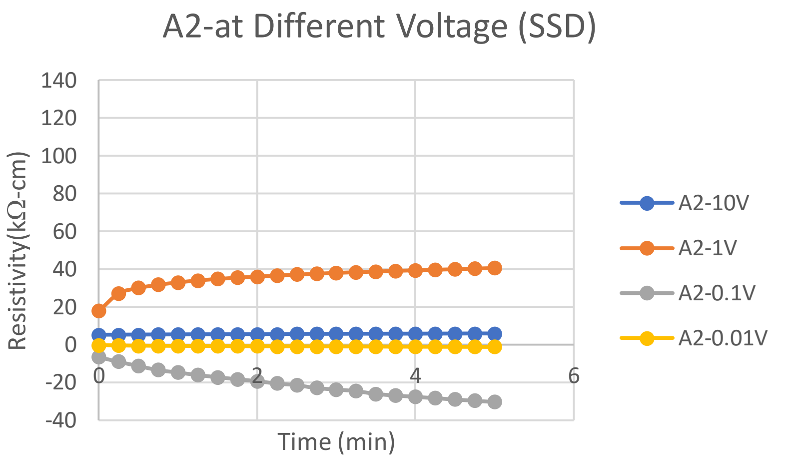


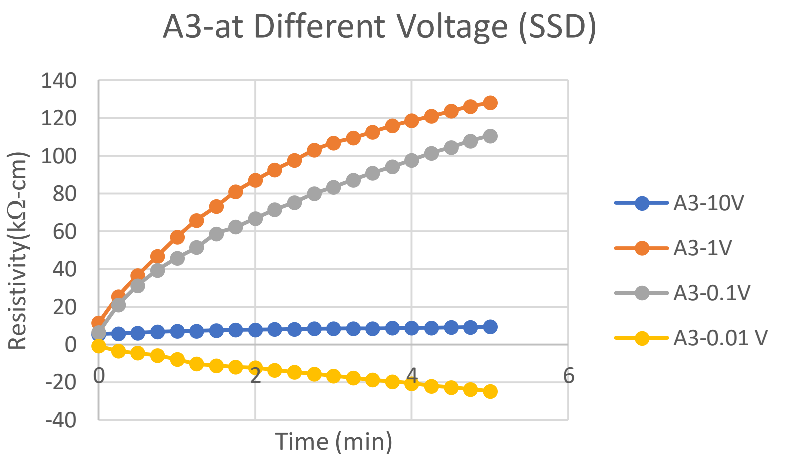


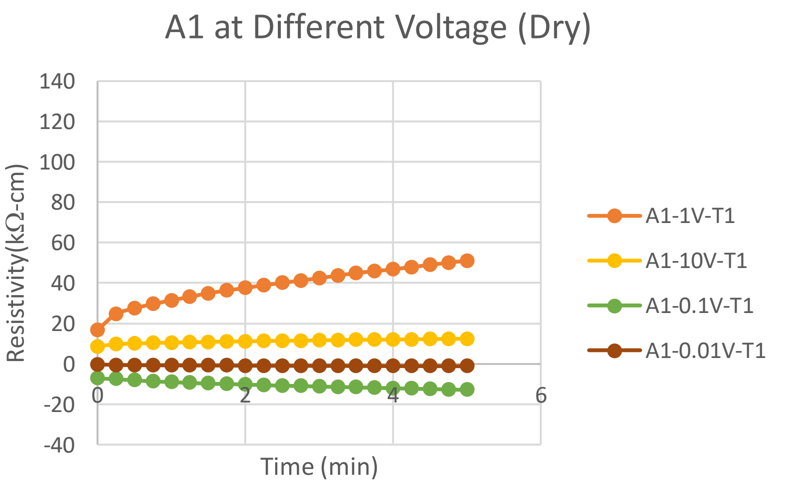


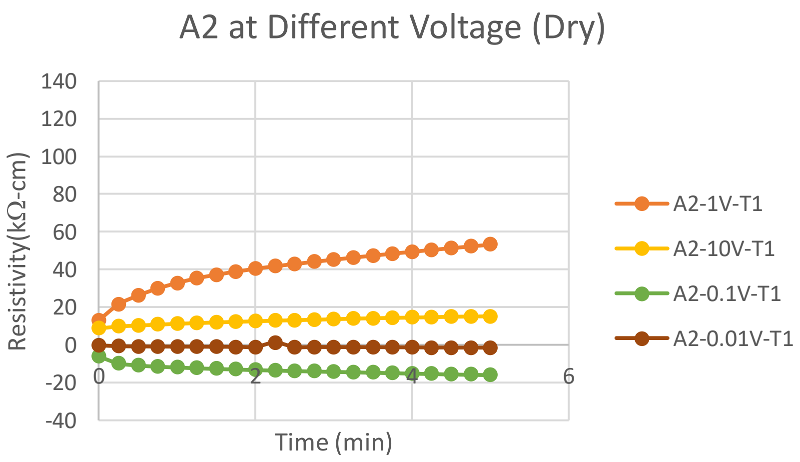
Static Resistivity at different Voltage of Specimen Set A (Both SSD and Dry)

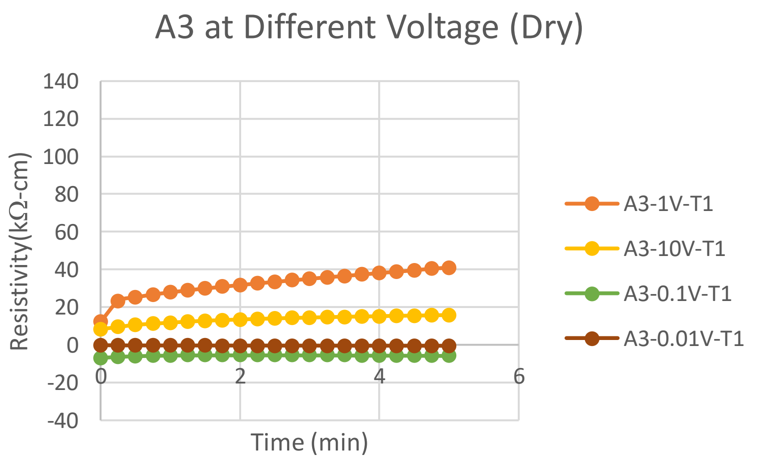












Conclusion

- 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

- Han, B.; Ding, S.; and Yu, X. (2015) Intrinsic self-sensing concrete and structures: A review. Measurement, 59: p. 110-128.
- Wen, S.; Chung, D.D.L. (2006). Model of piezoresistivity in carbon fiber cement. Cem. Concr. Res. 36, 1879–1885.
- Teomete, E.; Kocyigit, O.I. (2013). Tensile strain sensitivity of steel fiber reinforced cement matrix composites tested by split tensile test. Construction and Building Materials, 47: p. 962-968.
- Xiang Hua,b, Caijun Shia,∗, Xiaojin Liua, Jiake Zhanga, Geert de Schutterb (2019) “A review on microstructural characterization of cement-based materials by AC impedance spectroscopy”. Cement and Concrete Composites 100 (2019) 1–14

Any Questions?