Concrete Conductivity: Effects of temperature, saturation and air content

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Background
- Joint deterioration manifested itself as cracking and spalling of concrete in the vicinity of both longitudinal and transverse joints (Fig. 1 (a)).
- Under service conditions, the temperature, pore solution concentration, and degree of saturation of concrete near the joint vary continuously.
- Electrical conductivity, which also depends on the aforementioned parameters, might offer a means of monitoring changes in these parameters over time and improve our understanding of the cause of deterioration.
- This study examined how temperature, saturation level, and air content individually affect the electrical conductivity of concrete.

Results
- The initial resistance was measured immediately after vacuum saturation.
- Conductivity has a one-to-one relationship with its moisture content.
- In other words, formation factor can be interpreted as a measure of the volume of the pores and their connectivity.
- Therefore, we could use the formation factor to quantify the microstructure of the concrete and hence use that relationship to describe the effect of air content on conductivity of concrete.
- The present study will model the conductivity of concrete to its air content using formation factor and pore solution conductivity ($\phi_0$).

General Approach
- Concrete cylinders (4” x 8”) were cast using mixture proportions (see Table 1).
- The cylinders were cured at 23°C and 100% RH for at least 28 days.
- 2” thick discs were cut, vacuum saturated and exposed to different conditioning as described in the following sections.
- After conditioning electrical resistance was measured and electrical conductivity calculated.

Electrical Conductivity and Temperature
- Arrhenius relationship: can be used to model the effects of temperature on conductivity (Eq. 1).
- Other researchers have verified this relationship for concrete at temperatures ranging between 0°C to 50°C.
- This research evaluates the applicability of Arrhenius relationship for temperature ranging between -18°C to 23°C.

Electrical Conductivity and Temperature Level
- Conductivity has a one-to-one relationship with its moisture content.
- This relationship can be modeled using Eq. 2.
- After vacuum saturation, the resistance was the same as the samples were measured.
- Paste samples with w/c similar to concrete were cast and squeezed after curing for 28-days to extract pore solution and to measure its conductivity (Fig. 2).

Mixture Proportions and Sample Conditioning
- Mixture proportions used to study the effects of temperature are summarized in Table 1, column (1).
- After vacuum saturation, samples were conditioned to temperatures of 23°C, 15°C, 10°C, 5°C, -5°C, -10°C, and -18°C.
- The temperature was monitored using embedded temperature sensors (Type T).
- The sample conductivity was calculated from electrical resistance which was measured after each of the aforementioned temperatures was attained.
- The samples were then allowed to dry to desired mass to attain saturation levels of 95%, 90%, 85% and 80%.
- Resistance was measured when each of those saturation levels was attained.

Conclusions
- Concrete conductivity follows Arrhenius relationship for temperatures ranging between -18°C to 23°C.
- The concrete conductivity reduces by 30% when its saturation level is reduced from 100% to 80%.
- Segregation can affect the concrete conductivity.
- Concretes with higher air contents are difficult to saturate compared to concretes with lower air content. Therefore increasing air content might postpone the deterioration of joints by freeze-thaw damage.
- When saturated, concrete with higher air content demonstrates higher conductivity.

Future Work...
- The results of this preliminary testing will be used to design experiments which will attempt to quantify the microstructural deterioration, using conductivity, occurring in concrete when exposed to freezing and thawing in presence of deicing salt solutions.
- Comparing conductivity information from laboratory testing with conductivity values obtained while testing samples extracted from cores drilled out of deteriorated and non deteriorated joints of concrete pavements might provide us further understanding of the reason of premature joint deterioration.