Joint Transportation Research Program

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Electrical Testing of Cement Based Materials: Role of Testing Techniques, Sample Conditioning, and Accelerated Curing

Introduction

To improve the durability of concrete pavements, concrete bridge decks, and other transportation elements there has been an emphasis placed on developing test methods to measure the durability of concrete mixtures. Tests for durability have been slow in implementation since they are time consuming to perform and often have high equipment costs. As such, these tests have are not ideal for use in a quality control setting. This project examined the potential for using electrical testing on concrete as a potential surrogate for obtaining information on ion and fluid transport.

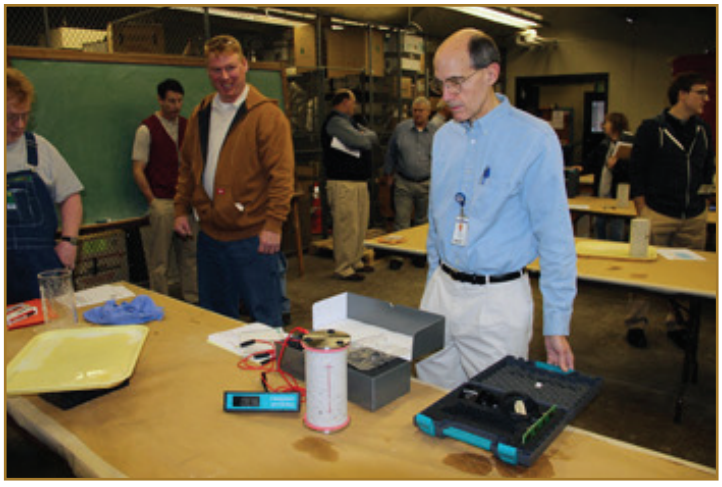
The interest in rapid electrical measurements is high since it uses economic testing equipment whose measurements can be completed in a very short amount of time (on the order of one minute per sample). While several groups have used electrical testing over the last century to measure properties, this study has worked on details that are needed for the development of a more comprehensive standard testing protocol. The testing procedure is relatively straightforward. As a part of SPR-3657: Rapid Method of Mixture Acceptance, Indiana Department of Transportation (INDOT) district testing engineers and their technicians were trained. However, the data interpretation and sample conditioning process appears to make standard development a bit more challenging, especially when accelerated curing is used, as discussed in this report.

The electrical resistivity of concrete is related to the resistivity of the pore solution, the porosity of the concrete, and the tortuosity of the pore network. With the development of portable units that can be taken into the field, rapid measurements that can take less than one minute are gaining increasing interest as a quality control or mixture acceptance test method. This project has investigated the variability of these test methods as well as factors affecting measurements, including moisture and degree of saturation, temperature, geometry, leaching pore solution, and high temperature conditioning. This work describes how electrical resistance measurements should be corrected for geometry to obtain a geometry-independent resistivity. This work has shown that sample conditioning can influence the pore solution properties and degree of saturation considerably and that these factors need to be accounted for to obtain accurate measures of transport properties. This report outlines each of these effects.

Many research studies have evaluated the relationship between resistivity and the rapid chloride permeability test (RCPT). The experimental fits from the various research studies do not match the relationship from first principles, but a reasonable agreement is noted. One important observation is that while typically low values from RCPT are considered characteristic of high quality concrete, this corresponds to higher measurements from resistivity tests.

Major Findings

- This work has indicated that geometry correction factors are needed to convert resistance measurements



Mr. Kurt Sommer, Crawfordsville District Testing Engineer, conducts a resistivity test during a training session co-hosted by the Office of Materials Management and Purdue University in January, 2013.

into the geometry-independent value for resistivity or conductivity.
- This work has shown that for the uniaxial cylinder test a coefficient of variation of 4.4% was obtained, leading to a within-laboratory precision of 12.4% and a multi-laboratory precision of 37.38%.
- This work has shown that temperature can dramatically influence resistivity. A correction for measurements is needed when the sample is a temperature other than the reference temperature. This can substantially influence the results, and a correction factor has been proposed that is based on the pore solution composition.
- This work has shown that the degree of saturation can dramatically influence resistivity. A saturation function is proposed that accounts for drying as well as the concentration of pore solution.
- The work has confirmed that, in general, for a standard 100 × 200 mm test cylinder, the ratio of surface resistivity to uniaxial resistivity is 1.8 to 1.9 for a homogenous material; however, if the material is heterogeneous (due to drying or leaching), this value changes.
- This project has also illustrated the importance of ionic leaching. Specifically, when stored in lime, saturated water alkalis and hydroxide ions can leach from the pore solution into the surrounding pore solution. Additionally, the report discusses how ionic leaching would impact different concretes differently.
- It was shown that accelerated curing requires testing temperature correction and curing temperature correction. This leaching problem is also a temperature-related process, so specimens stored in lime water at different temperatures will show drastically different resistivity measurements, due in part to ionic leaching.
- A direct correlation is discussed between electrical resistivity and the rapid chloride permeability.

Implementation

The following suggestions are provided for implementation.

- Resistivity tests have the potential to be used as a mixture qualification tool. However, performance limits will need to be established for various INDOT applications. These can be based on historical performance or service life simulation.
- Resistivity tests can be used to replace RCPT testing, which could save INDOT money in terms of testing costs and could enable testing to be performed in district testing laboratories.
- It is recommended that resistivity testing be added to proficiency testing.
- It appears that INDOT should consider the specification of a formation factor for qualifying mixtures, which can be obtained from resistivity measurement normalized by the pore solution resistivity for a vacuum saturated sample. The pore solution can be determined using a calculation from the chemistry of the cement. Electrical measurements can be simultaneously performed using sealed specimens and this information can be used for quality control testing.

It is suggested that INDOT consider using the resistivity test as a quality control tool and mixture. Resistivity has been shown to be highly dependent on the paste content and water content in a concrete mixture, both of which are related to long-term durability. It is recommended that sealed resistivity measurements be conducted as a part of mixture qualification. Resistivity targets could be established to account for production variability and used to establish quality control limits. For this application, the use of a sealed specimen would be recommended.

Recommended Citation

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