Electrical-Based Durability Assessment of Ultra-High Performance Concrete

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Extended Abstract

Durability is a central element of the overall performance of ultra-high performance concrete (UHPC). Customary UHPC constituents and mix designs result in a material with a dense microstructure that is far more resistant to common degradation mechanisms than conventional concrete. However, the durability performance assessment methods often used for conventional concrete are calibrated for more porous materials and thus may not provide actionable information regarding the durability performance of UHPC. The community of practice that is beginning to use UHPC in aggressive environments needs tools to ensure that a proposed UHPC-class material will deliver the desired performance.

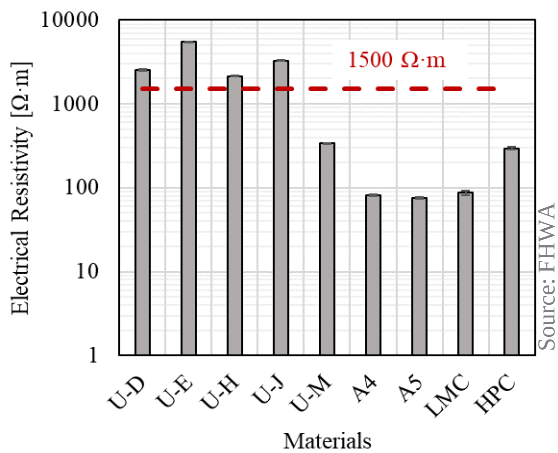
The objective of this study was to identify an appropriate, rapid test method to characterize the anticipated durability performance of UHPC-class materials. This study explored the use of electrical resistivity, non-steady-state (NSS) chloride migration, water absorption, and freeze-thaw tests to assess the durability-related properties of UHPC-class materials.

The five commercially available UHPCs (U-D, U-E, U-H, U-J and U-M) tested as a part of this study all had low water-to-cementitious materials ratios and no coarse aggregates and were intended to be used with steel fiber reinforcement. All products met the fundamental mechanical performance requirements for UHPC: The materials had a compressive strength greater than 18 ksi and had sustained post-cracking tensile mechanical resistance at a stress greater than 0.75 ksi. At the same time, the researchers tested four additional concrete mixes to assess their comparative performance. Two of these other mixes were conventional concrete mixes (i.e., A4 and A5); one was a latex-modified concrete (LMC); and one was a high-performance concrete (HPC).

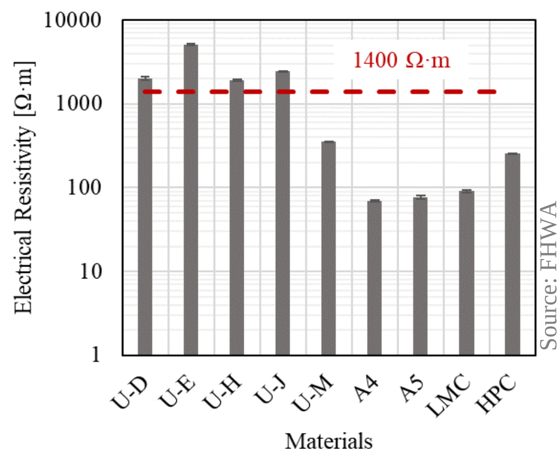
Four different tests were conducted as indicators of the durability performance of the materials. First, electrical resistivity was measured in accordance with American Association of State Highway and Transportation Officials (AASHTO) TP 119 in a uniaxial configuration, as seen in figure 1 (AASHTO 2022). Two conditioning methods were employed, 1) a default conditioning method as described in AASHTO TP 119 and 2) section 7 of AASHTO M 201 (AASHTO 2022; AASHTO 2021).

A wide range of resistivity values were observed in the UHPC-class materials at 28 days. One UHPC exhibited a resistivity value similar to that of an HPC, one order of magnitude lower than the remaining UHPCs, possibly due to a different pore structure, the presence of conductive inclusions, or both. The conditioning methods were found to affect resistivity development at an early age, and as such, two different electrical resistivity thresholds were proposed: 1) 1,500 Ω·m when conditioning in accordance with AASHTO TP 119, as seen in figure 2a, and 2) 1,400 Ω·m when conditioning in accordance with section 7 of AASHTO M 201, as seen in figure 2b.

Figure 1. Electrical resistivity test setup in uniaxial configuration.



(a)



(b)

Figure 2. Electrical resistivity of UHPCs and conventional concretes at 28 days conditioned in accordance with (a) default conditioning method of AASHTO TP 119 and (b) section 7 of AASHTO M 201 (AASHTO 2022; AASHTO 2021).

An NSS chloride migration test was performed at 28 days in accordance with NT Build 492 to evaluate performance (Nordtest 1999). As seen in figure 3a, the commercially available UHPCs with electrical resistivity above the AASHTO TP 119 threshold limit exhibited migration coefficients less than 0.5 x 10^{-12} m^2/s (AASHTO 2022). The one remaining UHPC product, U-M, displayed a similar migration coefficient to that of an HPC.

Rate of water absorption was measured in accordance with ASTM C1585 (ASTM 2020). The results of this test did distinguish between U-D, U-E, U-H, and U-J and the other concretes; these UHPCs have a significantly less permeable microstructure.

Finally, all the UHPCs and concretes were tested for freeze-thaw resistance according to ASTM C666 (ASTM 2015). All of the materials displayed good resistance to freeze-thaw degradation.

The findings from this study indicate that the water absorption and freeze-thaw tests provide an indication of durability performance and may help distinguish between different classes of materials. Electrical resistivity was found to be an excellent tool to rapidly characterize the durability performance of UHPC-class materials. As seen in figure 3b, AASHTO TP 119, whether conducted with the default or the AASHTO M 201 conditioning solution, was found to be easy to execute and to provide results that are qualitatively indicative of chloride migration within the concrete, a behavior that is commonly used in service life estimations of concrete structures.

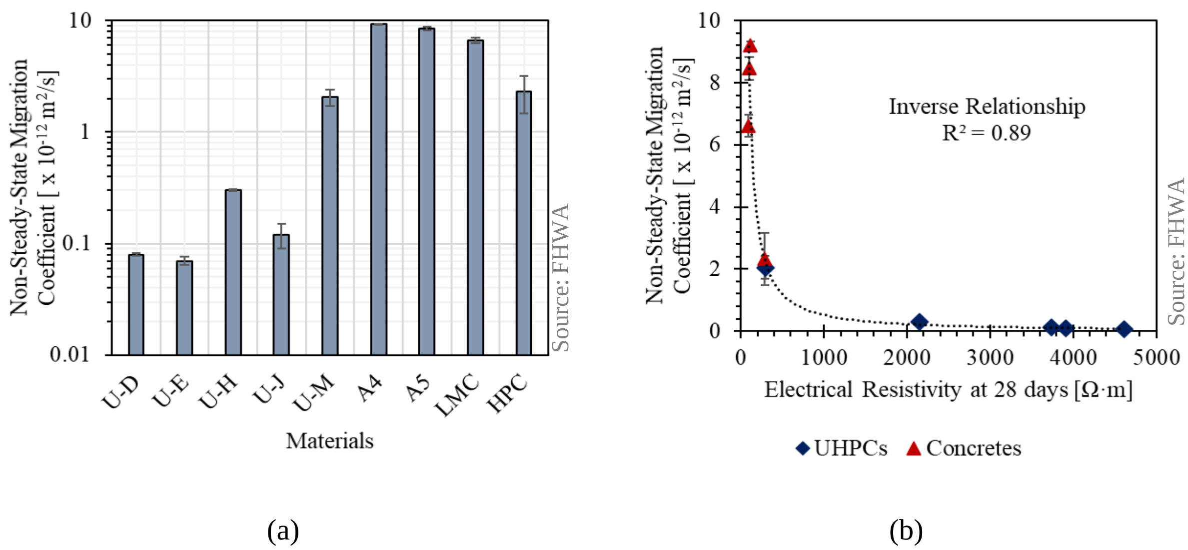


Figure 3. (a) NSS chloride migration in UHPCs and conventional concrete specimens tested in accordance with NT Build 492 at 28 days. (b) Correlation between electrical resistivity and NSS migration coefficient of UHPCs and conventional concretes at 28 days.

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