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A Refined, Self-Consistent Poisson-Nernst-Planck (PNP) Model for Electrically Induced Transport of Multiple Ionic Species through Concrete

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ABSTRACT

A fundamental re-look of the use of Poisson-Nernst-Planck (PNP) model for predicting electrically accelerated ionic transport through concrete is carried out. The PNP model is augmented with concentration-based diffusion coefficients and explicit considerations of transport path in the formulations since the electric field is distributed only along the connected pore path. The geometric tortuosity obtained from electrical property measurements is modified with a multiplicative correction factor that is a function of the ratio of dominant pore sizes in the specimen. Idealized models of the pore structure are used to arrive at this correction factor, which ranges between 1.5-to-3.0 for typically used concretes. Time-dependent changes in boundary conditions induced by the electrode reactions are also accounted for. The effect of chloride binding as a time-dependent process during the test, is also ascertained. The model is verified on a series of concretes of different water-to-cement ratios and containing different cement replacement materials (fillers and/or reactive materials) subjected to the non-steady state migration test.

Keywords: Poisson-Nernst-Planck (PNP) model; Transport Properties (C); Electrical Properties (C); Finite Element Analysis (C)

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