Numerical study and inverse analysis of a non distructive measurement method for oxygen diffusivity in partially carbonated concrete

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Résumé

Gas diffusivity in cementitious materials plays a crucial role in their durability analysis. This study aims to validate a non-destructive method for measuring oxygen diffusivity in cementitious materials using numerical modeling and experiments. This research provides improved understanding on the impact of various factors on gas diffusivity in heterogenous concrete, including the re-equilibration time, purge duration, leakage effects, and the presence of different layers.

The diffusion measurement method we develop uses a cell with a specific volume that is placed in contact with a cementitious material. The cell is purged and we observe how it gradually fills with oxygen that passes through the material. Assessing the gas permeability of cementitious materials using the diffusion measurement method can help evaluating their long-term durability by providing, for example, insights into their ability to resist deterioration caused by corrosion.

We optimize the dimensions and geometry of the measurement cell using numerical model. Diffusion is modeled using Fick's second law, which states that the rate of diffusion is proportional to the concentration gradient and the diffusion coefficient of the material. We solve this theoretical diffusion equation in 1D geometry analytically and numerically and in 2D geometry numerically. We define the optimal geometry of measurement cell as the one giving the minimum relative error between the analytical solution and the 2D numerical solution for a wide range of material properties (diffusion coefficient and layers size). The error quantification and fitting process involve comparing the numerical models to the analytical solution.

With numerical models, we quantify oxygen diffusivity and the accuracy of the measurement considering both the leakage through the measurement cell and the lateral leakage through the concrete. We analyze the effect of the presence of different layers in heterogenous cementitious materials.

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The results we obtain through numerical modeling provide validation for a non-destructive measurement method applied on a defined range of commonly used cementitious materials for both onsite and laboratory materials. We then conduct an experimental validation using laboratory samples.

The purpose of experiments is to verify in real conditions the accuracy of the method. By comparing the experimental results with the numerical simulations, we can evaluate the error between the two and check if our measurement technique works. In this validation process, we compare various aspects of the experiments and numerical simulations, such as the measurement time, the purge time, the time between two successive experiments and the characteristic lengths associated to the parameters mentioned earlier. By comparing these parameters with the corresponding values obtained from the numerical simulations, we can determine the accuracy of the experimental measurements. Inverse analysis is applied to experimental results to estimate parameters and validate the model using experimental data.
This new method for oxygen diffusivity testing for cementitious materials contributes to a better understanding of gas diffusivity in cementitious materials in real field conditions. It also offers a valuable complimentary tool for assessing the durability of concrete structures.