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Numerical evaluation of cement/bentonite interactions in engineered barrier systems

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We investigate the use of concrete in combination with bentonite in engineered barrier systems of radioactive waste deposits. Such barriers must remain stable for several tens of thousands of years, which is far longer than the lifetime of conventional infrastructure. In this study a multi-phase physicochemical method for the prediction of the long-term degradation of concrete by calcium leaching is presented.

We developed a unified approach that can be used for both, concrete and bentonite as well as their interaction in the engineered barrier system. To predict the degradation of cement by calcium leaching, solid-solution equilibrium of calcium ions and their transport are formulated on the basis of thermodynamic laws and calibrated to experimental data. In the bentonite domain, the proposed equilibrium formulation considers ions bound by ion exchange, as well as ion absorption on its microstructure. The parameters of the model are based on experiments with block samples of highly compacted bentonite. Transport of calcium ions is modeled by considering diffusion and advection in the pore structure.

We verified the model by comparing it to calcium leaching experiments of concrete in contact with bentonite. The analysis of the experiments revealed that the rate of deterioration is massively increased when the concrete was in contact with bentonite. This is caused by a high calcium concentration gradient between the concrete and the surrounding bentonite. In the bentonite a low concentration of free calcium ions in the pore water is maintained due to ion exchange and adsorption of calcium onto the clay.

We conclude that it is important to account for the effect of bentonite on the degradation process of concrete.