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Cementitious materials for oil-well abandonment and numerical simulations of cement durability at oil well conditions

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As the exhaustion of the oil resource progresses, abandonment of oil-wells becomes an inevitable issue for the petroleum industry. In the Danish Sector of the North Sea, approx. 2000 offshore old wells are planned to be plugged and abandoned permanently in the next few decades. Such operations usually employ cementitious materials functioning as a plug to block the inlets of the well-bore from the seabed, and thus to prevent flow of oil and gasses. Its structural integrity after abandonment is further required, to prevent leakage or environmental effects with time. That is, a cement plug that does not disintegrate with aging is needed. However, the design of such cement binder can be demanding due to its exposure conditions of a typical off-shore well with high temperature (60 - 80 °C), high pressure (≥ 300 bar) and in the presence of brine solution, gasses of hydrocarbon and CO_2 .

In this work, an experimental setup has been established which mimics the boundary conditions in the oil wells. White Portland cement (wPc), used as a model system, is hydrated with variable temperatures of 60°C and 80°C and a pressure of 300 bar for three different time lengths of 1, 7 and 28 days. Besides, an artificial brine solution is made and used to mimic the exposing environment where the cement plugs locate. The hydrated and exposed cements are characterized mainly by the solid-sate NMR and results from thermo-gravimetric analysis (TGA). Numerical simulations, along with experimental studies, can be an effective method for predicting the long-term performance of cement plugs and providing valuable insights into the underlying phenomena that drive cement plug deterioration in brine or carbonated brine solutions. In addition, numerical methods capable of predicting the changes in cement plug materials help select the cement composition and mix design, optimize the cost, and predict the service life. Therefore, in this study, a reactive transport model (RTM) framework is established for understanding the underlying phenomena that drive cement plug deterioration due to changes in pore solution composition and phase assemblage in cement plugs, and for predicting the service life of the cement plug.

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