Comparative Study of Alternative Binders for Concrete Sealing Structures in Rock Salt

Patrick Sturm, Gregor Gluth, Janis Moye, Solen Garel, and Hans-Carsten Kühne
Bundesanstalt für Materialforschung und -prüfung (BAM), Berlin, Germany (patrick.sturm@bam.de)

Alkali-activated materials (AAMs), hybrid cements (cements composed of Portland cement clinker, supplementary cementitious materials and an alkaline activator) and cements based on the principle of ‘Opus Caementicium’ (OC) potentially provide advantages over conventional cements for the use in sealing structures in rock salt, such as low heat of reaction and related thermal induced deformations (expansion and contraction) and autogenous shrinkage, all of which can lead to crack formation.

In this study several binders have been investigated by isothermal calorimetry and X-ray diffraction (XRD). Specific mix-designs of the AAMs were chosen for further investigations on the development of the mechanical strength of salt-saturated mortars, i.e. crushed rock salt was used as aggregates, under different conditions (23 °C/50 % r.H. and 40 °C/35 % r.H.) and compared to a ‘low-pH’-cement-based salt-saturated reference mortar.

After a reaction time of 7 days the heat of reaction of the hybrid cements was always lower than 70 % of that of an ordinary Portland cement (OPC), while the heat of reaction of the AAM and the OC was always lower than 20 %. For the hybrid cements Na2SO4 accelerated the early reaction of the Portland clinker, while Na2CO3 appeared to decrease the reaction and led to a shift of the second hydration peak (likely related to slag reaction) to later hydration times. Besides minor peaks in the heat flow after 4 days, the AAM and OC provided a rather continuous heat release over the considered reaction time.

The AAMs showed no signs of major crystalline reaction products; only traces of carbonates, alumina or zeolites were identified after 28 days. For the hybrid cements, semicrystalline C-A-S-H, portlandite and hydrotalcite were present in all samples as hydration products. Furthermore, in these systems the use of Na2SO4 lead to the formation of ettringite (AFT-phase), while the use of Na2CO3 lead to the formation of hemicarbonate (AFm-phase).

Compared to the ‘low-pH’-cement-based mortar, the AAM-based mortars had lower mechanical strength after 28 days. With increasing curing time the differences decreased. Increasing the temperature and decreasing the air humidity led to an acceleration of the strength development at early ages, but also to a decrease of the final strength for specific AAM-based formulations, suggesting the introduction of microcracks due to drying shrinkage. The exception was the two-part AAM-formulation, which provided the highest final strength in the considered period (91 days) independent of the storing conditions.