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Technology Information

Sealing of Rock and Soil Formations by Directed Gypsum Crystallization

Fundamentals

The formation of gypsum as a result of coupled dissolution and precipitation processes can change the hydraulic conductivity of large soil or rock formations significantly. Such processes, occurring for example in waste rock dumps containing limestone, however, need long times. Although the gypsum solubility is relatively high (2.5 g $CaSO_4$/L), long time stability has been proven. Deeper horizons are protected against the infiltration of water and oxygen.

The idea of the newly developed technology of sealing by induced gypsum crystallization is, to use artificially inducing crystallization processes, similar to those occurring in nature, to seal rock formations and to stop water inflows into mines. Solutions supersaturated in gypsum are prepared by mixing $CaCl_2$ solutions or $Ca(OH)_2$ suspensions with solutions containing SO_4^{2-} ions. Spontaneous crystallization is prevented by the addition of special precipitation inhibitors. These are able to stabilize supersaturated solutions temporarily.

Without precipitation inhibitor: $CaCl_2 + MgSO_4 \longrightarrow CaSO_4*2H_2O$

$Ca(OH)_2 + H_2SO_{4\ (aq.)} \longrightarrow CaSO_4*2H_2O$

fast, uncontrolled precipitation

In the presence of precipitation inhibitors: $CaCl_2 + MgSO_4 \longrightarrow Ca^{2+} + SO_4^{2-} + Mg^{2+} + 2\ Cl^-$

$Ca(OH)_2 + H_2SO_{4\ (aq.)} \longrightarrow Ca^{2+} + SO_4^{2-} + H_2O$

temporary stable solution

$\downarrow$

$CaSO_4*2H_2O$

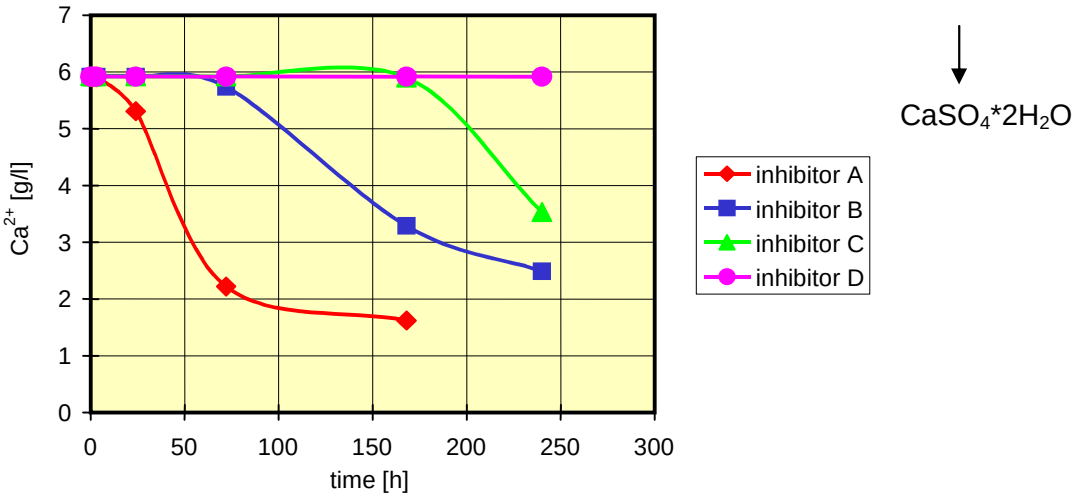

Fig. 1: Course of gypsum crystallizationdepending on the inhibitor used

The stability of the solutions depends on the inhibitor composition, its concentration, the temperature and the total degree of supersaturation (Fig. 1). It is possible to prepare solutions leading to the formation of up to 80 kg gypsum/m³. The stability can range from few minutes to hours or days. The flow of $CaSO_4$ supersaturated solutions through porous or fractured soil or rock formations results in gypsum crystallization within the flow paths. The formed crystals block fractures and pores (Fig. 2, 3) and cause significant reductions in the permeability. Sealing can be accompanied by the immobilization of contaminants.

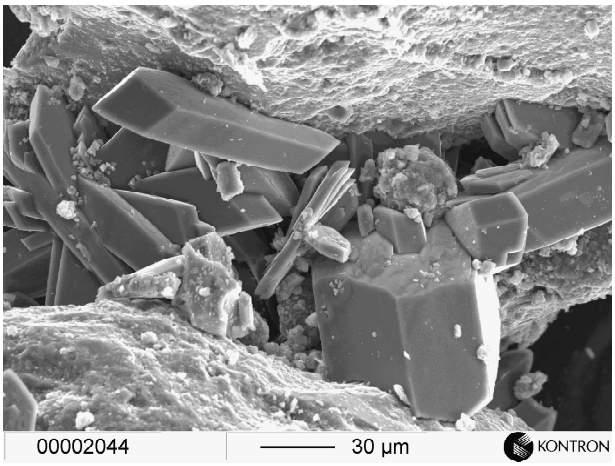

Fig. 2: Flow paths sealed by gypsum crystals

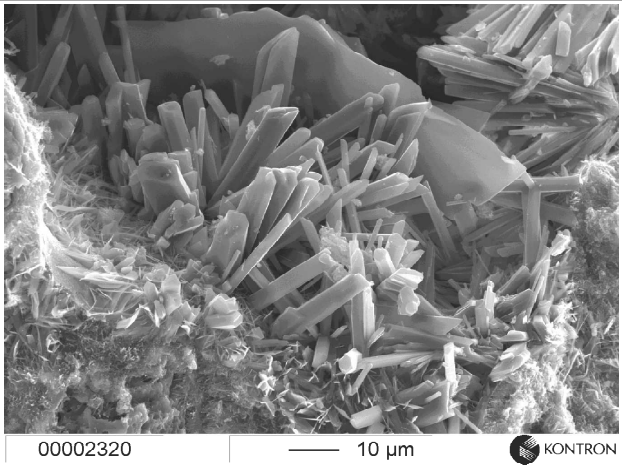

Fig. 3: Gypsum needles covering the surface

Applications

$CaSO_4$ supersaturated solutions are applied as grout for sealing of low permeable soil or rock formations. Depending on the temperature, sealing is achieved by the formation of gypsum or anhydrite. Both penetration and high pressure grouting can be used to bring the solutions in the areas that have to be treated. The crystallization time is adjusted by the solution composition. $CaSO_4$ solutions are able to penetrate even into smallest fractures and pores which can not be sealed by cementitious materials or chemical grouts.

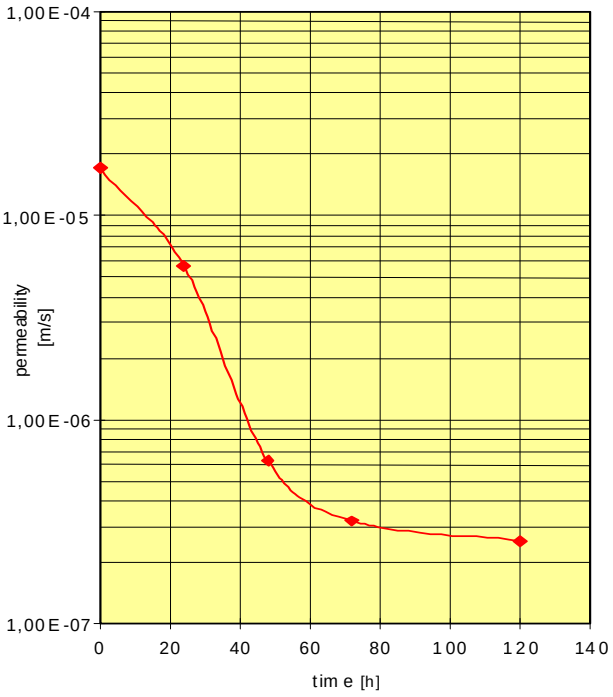

Fig. 4: Permeability reduction of a sandstone sample during treatment with $CaSO_4$ supersaturated solutions

For sealing of water inflows into mines, it is important that the solutions can be injected into areas far away from the inflow point. This means it is possible to grout the main flow paths, and gypsum crystallization takes place while the grout travels through the inflow area. Gypsum crystallization will lead to the gradual closure of flow routes in a manner similar to naturally occurring processes. It is essential that there is no necessity to fill the pore space or fractures completely with secondarily formed gypsum to achieve sealing. The reduction in permeability is caused by single grown gypsum crystals or slowly growing gypsum layers. These block the flow paths and cause a drastic reduction in permeability. $CaSO_4$ supersaturated solutions temporarily stable up to 120 °C can be prepared as well as solutions saturated in NaCl or NaCl/KCl.

The preparation procedure is fully applicable under field conditions and is based on the gradual mixing of concentrates of the components. In general, a replacement of two to three pore volumes results in a permeability decrease by more than 1 to 2 orders of magnitude. In most cases the grout can be prepared by using mine water or natural groundwater. Only non toxic, environmentally friendly chemicals are used.