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Technology Information
Sealing of Rock and Soil Formations by Directed Gypsum Crystallization

Fundamentals

Gypsum, a mineral occurring in many rock materials, has at 25 °C a solubility of 2.5 g/L water. Its solubility is lower in sulfate containing solutions. In many naturally occurring processes (for example, as a result of the oxidation of sulfide containing ores) as well as during water treatment, gypsum precipitation takes place. The reduction of the permeability of rock materials and the blocking of tubes by secondarily formed gypsum is well known. The idea of the newly developed process is, to artificially induce such processes in order to seal rock formations and to immobilize contaminants. Solutions characterized by concentrations above the normal solubility of gypsum or anhydrite can be prepared by mixing $CaCl_2$ solutions or $Ca(OH)_2$ suspensions with solutions containing SO_4^{2-} ions in the presence of precipitation inhibitors. These prevent spontaneous gypsum formation (Fig. 1).

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

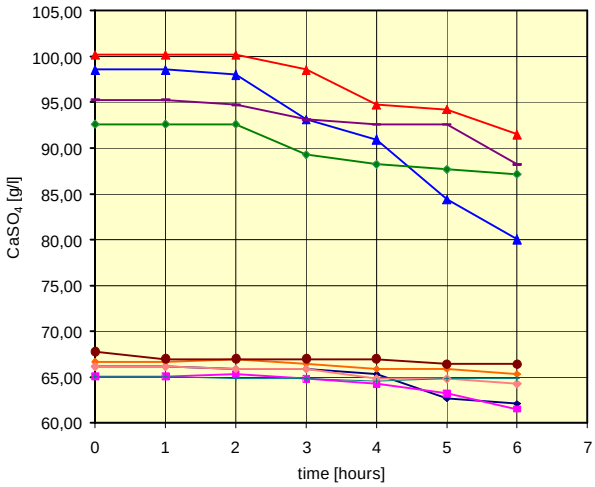
$Ca(OH)_2 + H_2SO_{4\ (aq.)} \longrightarrow CaSO_4*2H_2O$

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



depending

$CaSO_4*2H_2O$

fomation of layers, single crystals or sludges

on the solution composition

Fig. 1: Course of gypsum crystallization from extremely oversaturated solutions

The precipitation inhibitors are temporarily stable only. This allows to means, it is possible to adjust the timely stability of oversaturated solutions by the selection of the inhibitor and its concentration. Flowing of gypsum oversaturated solutions through porous or fractured rock formations leads to gypsum crystallization within the flow paths. A drastic reduced permeability is achieved. Grouts leading to gypsum crystallization between few as well as more than 200 hours can be prepared.

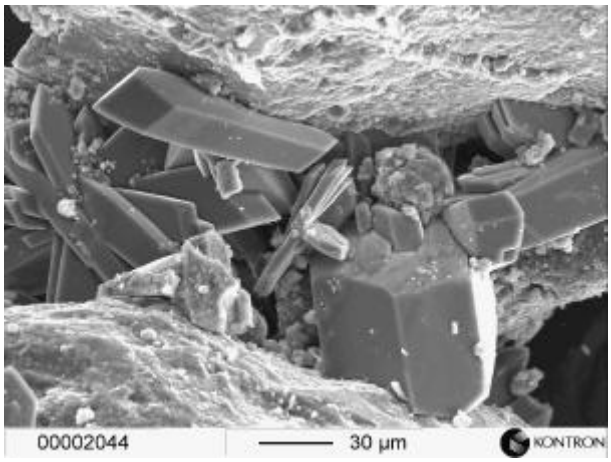


Fig. 2: Flow paths sealed by gypsum crystals

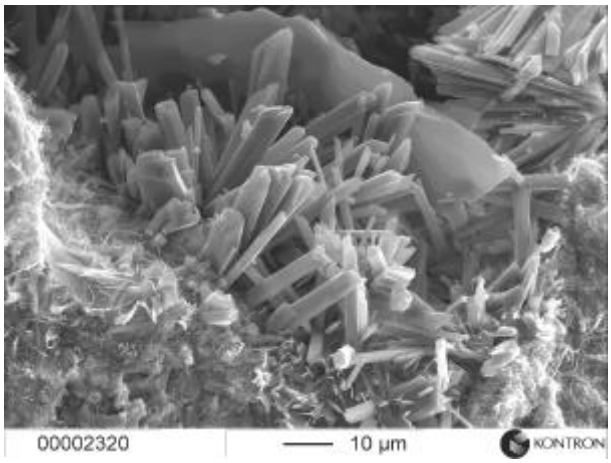


Fig. 3: Gypsum needles grown on sand particles

Applications

$CaSO_4$ oversaturated solutions can be applied both to solve geotechnical tasks and to immobilize contaminants. The preparation procedure is fully applicable under field conditions and is based on gradual mixing of concentrates of the components. Both penetration and high pressure grouting can be used to bring the solutions in the areas that have to be sealed. The setting time is adjusted by the solution composition. The grouts lead to a decrease of the permeability (Fig. 2, 4) as well as to the formation of protective layers on reactive mineral surfaces (Fig. 3). The formed minerals consist mainly of gypsum (or at higher temperatures of anhydrite) but also include hydroxides such as $Fe(OH)_3$. It is essential that there is no necessity to fill the pore space of fractures completely with secondarily formed gypsum to achieve sealing.

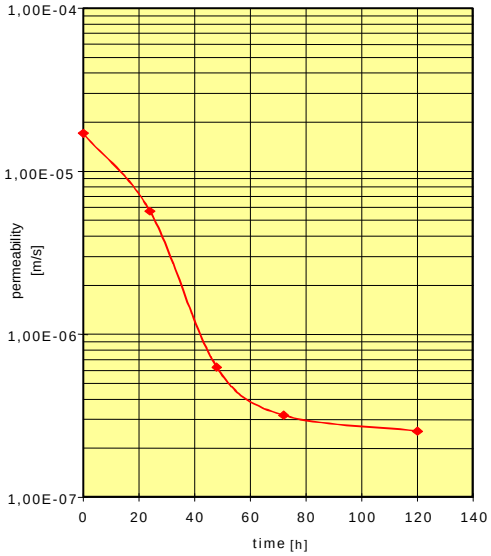


Fig. 3: Permeability reduction of a sandstone sample during treatment with a $CaSO_4$-oversaturated solution

Gypsum crystallization takes place while the grout travels through the rock or soil formation and leads to the gradual closure of flow routes in a manner similar to naturally occurring processes.

$CaSO_4$ oversaturated solutions temporarily stable up to 120 °C can be prepared as well as solutions saturated with 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.

Costs

The amounts of grout necessary for sealing rock or soil formations have to be determined by experiments on real samples. In general, a replacement of two to three pore volumes results in a permeability decrease by 30 to 40%. In most cases the grout can be prepared by using mine water or natural groundwater. The costs of chemicals per m^3 final mix are low. They depend on the total amount of grout and the degree of $CaSO_4$ oversaturation.

Safety

Only non toxic, environmentally friendly chemicals are used. The pH of the solution lies between 6 and 7.