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Self-Sealing of Fractures in Clay Rock

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Excavation of a deep geological repository for disposal of radioactive waste in clay formations generates fractures around the openings, which may act as pathways for wa-ter transport and radionuclides migration. Because of the favourable properties of the clay rocks such as the rheological deformability and swelling capability, a recovery pro-cess of the excavation damaged zone (EDZ) can be expected due to the combined im-pact of rock compression, backfill resistance, and clay swelling during the post-closure phase. For the safety assessment of a repository, the self-sealing process and impact on water and gas transport through the EDZ have to be characterized, understood, and pre-dicted. GRS has experimentally investigated the self-sealing behaviour of fractures arti-ficially created in samples of the Callovo-Oxfordian claystone at Bure in France and the Opalinus clay at Mont-Terri in Switzerland. Major findings are summarized as follows.
High stresses generate microcracks, which propagate and coalesce to a network when the peak failure stress is reached. The fracturing results in a spontaneous increase of the permeability by up to several orders of magnitude, depending on the minor principal stress. When the stress normal to the fracture planes is increased, the fractures tend to close up and correspondingly, the fracture permeability reduces.
As water enters and flows through fractures, the clay matrix takes up the water and ex-pands into the interstices. The water-induced swelling, weakening and slaking of the claystone leads to clogging and sealing of the fractures. Consequently, the hydraulic conductivity decreases by several orders of magnitude down to very low levels of 10-19 to 10-21 m2 even at low confining stresses of 2-4 MPa. Moreover, the sealing of the frac-tures is not significantly affected by thermal loading in a temperature range between 20 °C and 90 °C. The very low water permeabilities of the resealed fractures are in the same order as that of the intact claystone.
Before full water saturation, fractures act as preferential pathways for gas. However, af-ter full water saturation, gas entry and penetration into the resealed fractures require a certain gas pressure to overcome the capillary thresholds. The gas entry/breakthrough pressure is controlled by the degree of fracture sealing which is in turn depending on the confining stress. It was observed that the gas breakthrough pressures in the water-saturated and highly-resealed claystones are still lower than the confining stresses.
Generally speaking, the high sealing capacities of the studied claystones hinder water transport and thus radionuclides migration through the EDZ, but allow gas flow without over-pressurisation and fracturing the surrounding host rock. These significant ad-vantages guarantee the integrity and sealing functions of the geological and engineered barrier systems and hence the long-term safety of the repositories in the clay formations.