Asse Mine (Germany)

Description: Excavation-disturbed zones (EDZs) are formed in all types of rocks as a consequence of the opening of cavities. In salt formations EDZs can extend up to 2 m into the rock salt. These zones represent areas with permeability increased by orders of magnitude compared to that of undisturbed rock salt. In a repository, where low permeable sealings are used as part of a multi-barrier concept, the increased permeability of the EDZ may lead to a reduction of the flow resistance and an increased brine flow through this section.

The primary reason for EDZ formation is the stress imposed by excavation that leads to dilatancy which results in an increase in porosity and permeability. However, the permeability of EDZs can be reduced when the stress returns to a homogeneous state, e.g. after creep of the rock onto engineered barrier systems.

The permeability distribution and the extension of the excavated rock salt was measured at various test sites in the Asse salt mine in Northern Germany, near Braunschweig. One drift, the so-called bulkhead drift is especially interesting with regard to potential long-term behaviour of the EDZ which was mined in 1911. A 25 m long section of the drift was equipped with a liner of cast steel tubings in 1914, and the void between the liner and the drift surface was backfilled with concrete. This drift can be regarded as a technical analogue for the development of an EDZ in a drift around a bentonite or concrete sealing as it is foreseen in a repository in salt. From the stress and permeability measurements taken in the excavation-disturbed zone around this bulkhead, information on the healing process of the EDZ in the long-term can be derived. A view into the bulkhead drift is shown in Figure 1.

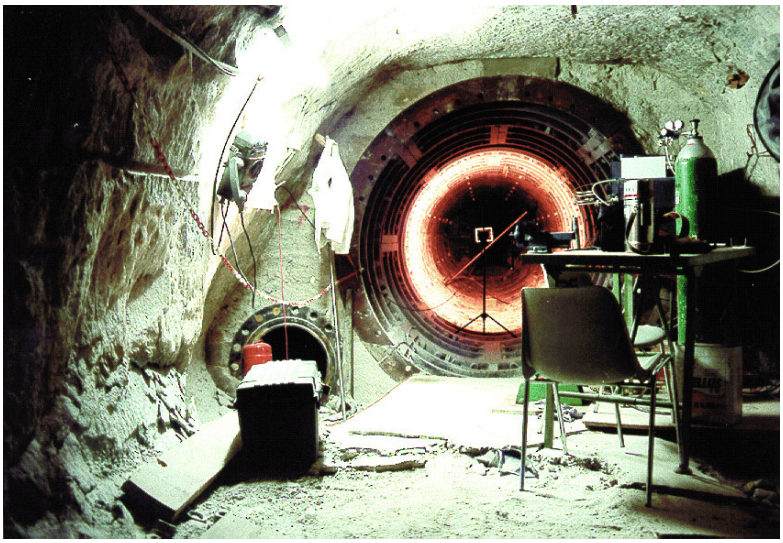

Figure 1: View into the bulkhead drift in the Asse salt mine showing the permeability measurement system

As schematically shown in Figure 2, four boreholes were used for permeability measurements. Horizontal, vertical and 45°-inclined boreholes were drilled through the steel liner into the rock salt. The fourth borehole was drilled vertically into the floor outside the lined part of the drift in order to obtain a comparison between the lined drift and the open drift. The permeability distribution around the bulkhead was measured by gas injection tests and the results of the permeability measurements are also presented in figure 2.

Below the open drift, a typical EDZ is present. It extends about 1.5 m into the rock, and the permeability rises above 10^{-16} m^2. This confirms the results of a great number of permeability measurements at other test sites in the Asse salt mine. At all test sites with open drifts, an EDZ extension about 1.5 m into the floor and not more than 0.5 m into the walls was observed. As was

found using various test setups for measurements close to the open surface, the permeability may rise to values of 10^{-16} m^2 to 10^{-15} m^2, in comparison to around 10^{-21} m^2 of the undisturbed salt.

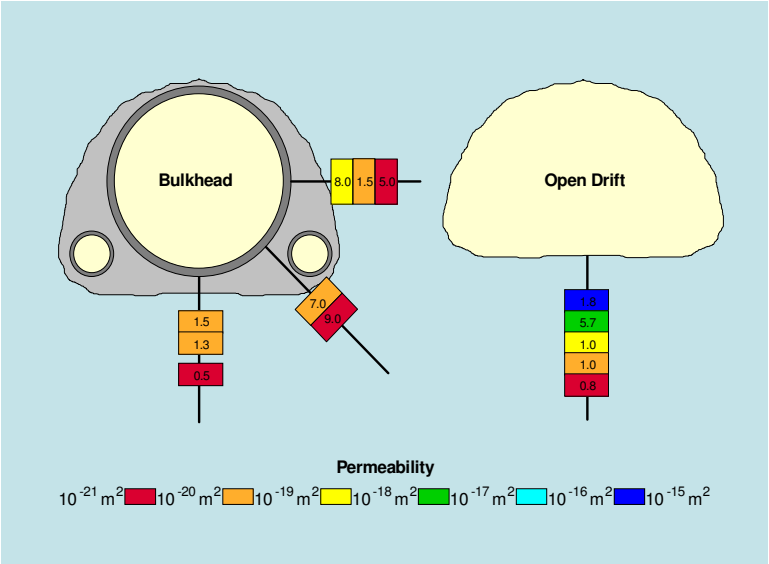

Figure 2: Measured permeability values in the boreholes around the lined drift (left) and below the open drift (right).

Around the lined part of the drift permeability is completely different. Other than the horizontal borehole close to the drift surface, all permeability values remain below 10^{-19} m^2, which is considerably lower than the typical EDZ values. These low permeabilities are due to the stress state which is characterised by high normal and negligible deviatoric stresses, which have also been demonstrated by supporting calculations. The original permeability of undisturbed salt, however, is not yet reached. Microstructural investigations on cores from both the lined and the unlined part of the drift seem to indicate that this may be due to the fact that the existing microfractures were closed by the stress, but did not disappear.

Healing of the EDZ is not only a function of stress state, but also strongly time-dependent. The time dependence could not be clearly determined in this study. In case of natural dry rock salt, with about 0.02 wt% water in the Asse mine, 90 years under high compressive stress and negligible deviatoric stress were not sufficient to completely heal the EDZ around the bulkhead drift. However, this study clearly shows that a partial healing of the EDZ with reduction of permeability by orders of magnitude was observed.

Relevance: The velocity of inflow of brine into a repository and outflow of contaminated brine out of the repository is important for performance assessment. This velocity is a function of the permeability of backfilled and sealed drifts in the repository. If the permeability of the EDZ around the sealed drift is higher than that of sealed drift itself this would facilitate the brine transport and thereby facilitate radionuclide release from the repository. Therefore geometry, permeability, and temporal development of EDZs are important parameters for performance assessment.

Position(s) in the matrix tables: The study illustrates the process of physical integrity of the EDZ in near-field rock.

Limitations: This study is limited to the behaviour of EDZs in rock salt. It shows that the permeability of an EDZ around a sealed drift in rock salt is reduced within 90 years by orders of magnitude in comparison to EDZs of fresh excavated drifts. However, a function for the time dependence of the EDZ could not be derived from the study. This study is representative for dry rock salt with water contents of about 0.2 wt%. The healing of an EDZ is expected to be much faster for rock salt with higher water content. Furthermore it should be noted that the healing process is dependent on the stress induced convergence of the salt dome, e.g. existence of

anhydride veins could significantly reduce convergence. This has to be considered for the transferability of the results from Asse mine to other salt domes.

Quantitative information: Permeability distributions in the EDZ around a sealing 90 years after excavation are available.

Uncertainties: Comparison of EDZ produced by old mining techniques with to those produced by current technologies. The effects of differences in compositional variations in rock salt formations.

Time-scale: The time-scale addressed by the study is human (90 years).

PA/safety case applications: The results of this study are rather new and have not been used in PA so far. In recent performance assessments e.g. for the Morsleben repository the EDZ has been considered as a zone with higher permeability. It has been assumed, that the permeability of the EDZ will not change in time, i.e. no credit was taken from the healing process.

Communication applications: None known.

References:

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Added value comments: None to add.

Potential follow-up work: Currently no follow-up work is being considered at this site.

Keywords: excavation disturbed zone (EDZ), rock salt, permeability, healing

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