DESIGN AND HYDRAULIC MODELLING OF BENTONITE ELEMENTS FOR SHAFT SEALING SYSTEMS

Matthias Gruner[1], Michael Jobmann[2], Thomas Wilsnack[3]

1. Institut für Bergbau und Spezialtiefbau, TU Bergakademie Freiberg, D-09596 Freiberg, Germany (matthias.gruner@mabb.tu-freiberg.de)
2. DBE Technology GmbH, Eschenstraße 55, D-31224 Peine (jobmann@dbe.de)
3. IBeWa-Consulting, Lessingstr. 46, D-09599 Freiberg, Germany (th.wilsnack@ibewa.de)

Shaft sealing systems for repository mines often include bentonite sealing elements. The dimensioning of the bentonite sealing elements on the one hand and the hydraulic modelling of the complete system including the host rock, the contact zone between bentonite and host rock, and the EDZ are important steps during the development of shaft sealing systems.

The key parameter is the tolerable maximum of the integral fluid flow through the sealing element, the contact zone, and the EDZ. A swelling pressure of > 1 MPa guaranties the tightness of the contact zone between bentonite and host rock. Therefore, the main input parameters for calculations are the thickness and the effective permeability of the EDZ. For the saturated bentonite element, the necessary relative length L_s/A_s can be calculated for the tolerable fluid flow Q_{max} (Figure 1). All hydraulic parameters (permeability of sealing material $k_{f,S}$ and the EDZ $k_{f,R}$, radius of the sealing element R and thickness of the EDZ x) are summarized in the dimensionless parameter G. Theoretically, the resulting swelling pressure developing in the sealing element as well as its permeability depend on the effective dry density of the bentonite.

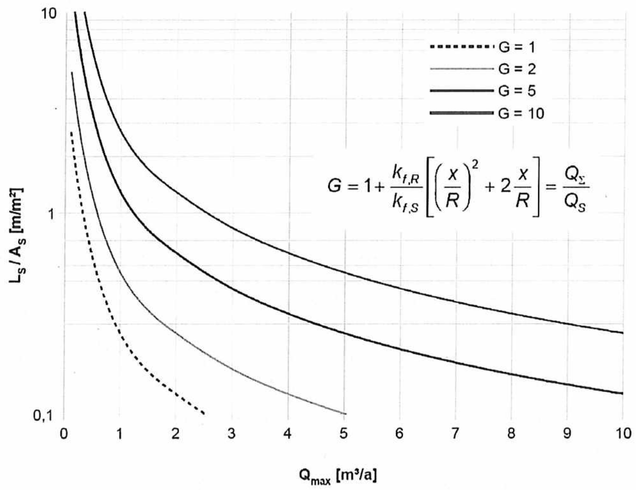

Figure 1: Relative length of the sealing element versus maximal tolerable fluid flow for different values for parameter G and for a hydrostatic fluid column H = 800 m, the hydraulic conductivity of the sealing material $k_{f,S} = 10^{-11}$ m/s [1]

As shown by experiments, the swelling pressure developing in the bentonite material is mainly influenced by its smectite content, the initial water saturation, and the chemical composition of the liquid.

A first evaluation of known results of swelling pressure and permeability experiments leads to a correlation of swelling pressure versus smectite content normalized to the pore volume shown in Figure 2. The scattering of parameters is caused by the variety of influencing processes, i.e. type of liquid, initial water content, test method, type of material, additive. Despite these influences, it seems to be possible to find a well founded regression in order to predict the swelling pressure as a basis for the sealing design. It is necessary and it seems to be possible to find dependencies in this way for the other flow-relevant parameters, e.g. gas and liquid (brine) permeability, capillary pressure, and gas breakthrough (threshold) pressure.

Although the focus is on liquid flow processes, gas flow through a shaft sealing system in rock salt should be considered, too. An increase in gas pressure at the bottom of a shaft sealing system cannot be excluded. This will mainly be caused by progressive convergence in the mine and partly by gas producing reactions (remaining artificial material). The pore pressure in the saturated and unsaturated swellable bentonite results from interactions between the capillary pressure (capillary suction) and the swelling pressure [2].

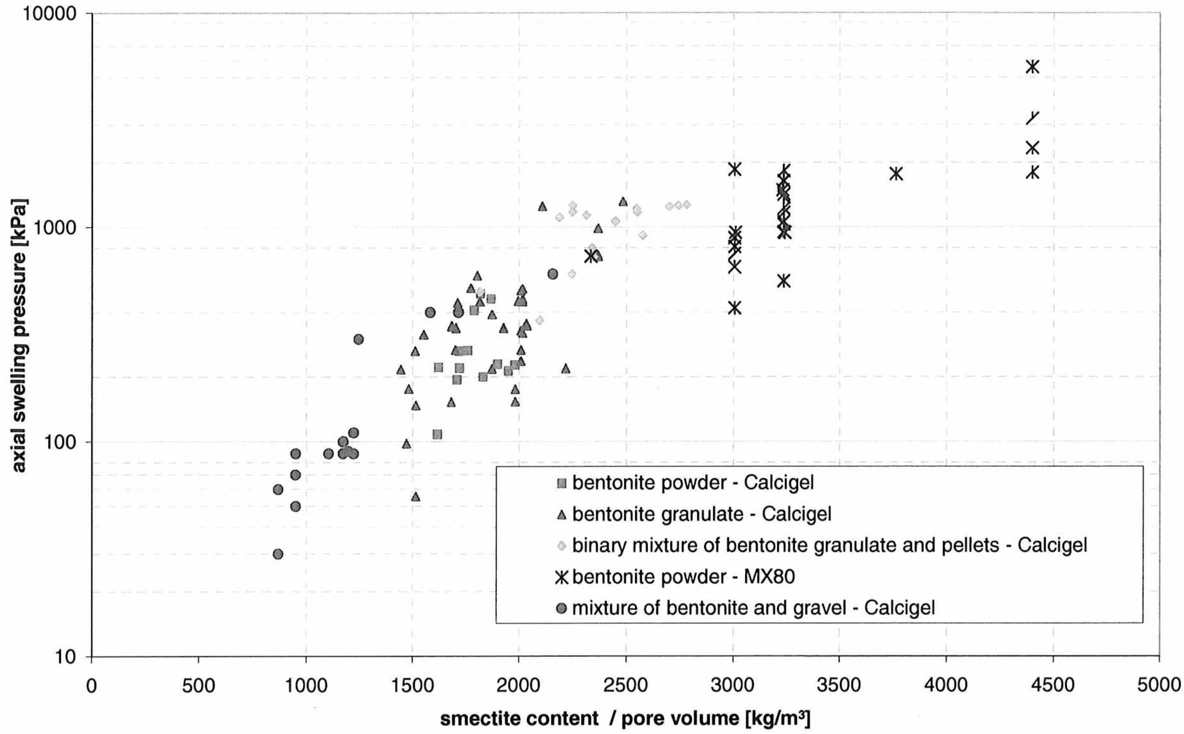

Figure 2: Swelling pressure for several bentonite materials and solutions versus smectite content normalized to the pore volume (various results)

Therefore, understanding and modelling gas and fluid flow processes in the bentonite sealing elements requires representative parameters for, e.g., swelling pressure, gas breakthrough pressure, capillary pressure, porosity, and pore size distribution for the initial and completely saturated state. The entirety of the processes and interactions during progressive saturation and swelling, additionally influenced by compaction processes of the bentonite and convergence of the host rock, are very complicated. When assessing the hydraulic processes and the model based prediction, further effects have to be evaluated: density change due to compaction of the bentonite element, rise of gas pressure and beginning of gas flow, heterogeneous distribution of parameters (e.g. density, porosity, saturation, permeability), and impairment of the sealing performance due to the higher permeability of the contact zone.

Based on representative input parameters the dominant flow processes under unsaturated and saturated conditions must be analysed, taking into account the time-dependent pressure on both sides of the sealing system. Hydraulic modelling has already been performed for small-scale pilot sealing tests as well as for a large-scale bentonite sealing element in the shaft sealing experiment Salzdetfurth. The new project "Sealing systems for radioactive waste repository (ELSA)"[1] takes into account the advanced knowledge about the processes in order to develop a sound strategy for process modelling. The results are essential for sealing concepts, sealing designs, specifications of the bentonite material, and emplacement of the sealing elements.

[1] Gruner, M.: Einsatz von Bentonit im Entsorgungsbergbau. Bergbau – Zeitschrift für Rohstoffgewinnung, Energie, Umwelt 61 (2010) Nr. 9, 394 - 403

[2] Agus, S.S. (2005): An experimental study on hydro-mechanical characteristics of compacted bentonite-sand mixtures. Dissertation. Bauhaus-Universität Weimar

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