Abstract

The load-bearing behaviour of caverns constructed in salt formations to extract minerals (solution mining) or to store energy (crude oil or natural gas) have been the focus of scientific research for many decades. This research previously concentrated on confirming the stability and safety of the caverns during construction and operation. During the past 10 years, the focus has also partially fallen on the questions involving cavern abandonment and their long-term behaviour. Various options are available for abandoning caverns: the preferred option in most cases – also on economic grounds – is filling the caverns with water / brine and sealing the access borehole. The load-bearing behaviour of fluid-filled caverns has therefore been the focus of technical and scientific investigations, particularly at an international level. The central aspect here is the question concerning the conditions, the scale, the routes by which brine may escape from the caverns, and the consequences were this to happen.

This paper presents a new approach to the analysis of the load-bearing behaviour of sealed fluid-filled salt caverns. This primarily concerns the process of brine infiltration into the originally impermeable salt rock, and the physical modelling and numerical simulation of this process. If the infiltration front reaches a porous rock formation, the infiltration process is followed by a flow process along the previously created migration paths.

This paper deals with the following:

(1) The state of the art and the new theoretical principles; laboratory characterisation and modelling approaches for the infiltration process; implementing the results in a numerical simulation

(2) The numerical simulation of the infiltration process and the subsequent flow process in a reference cavity in a rock salt mass

(3) Validation of the newly developed methodological approach by back-analysing a real cavern construction example (field test)

In addition, this paper also includes a treatment and discussion of the aspects of fluid (water, brine) re-heating after sealing in, and the degeneration of migration paths (fissure closure and re-healing).

This approach is currently being broadened to include: the modelling and numerical simulation of infiltration processes in impermeable and very low permeable formations where the infiltration fluid is a gas; conditions affected by anisotropic formation properties associated with different textures; and 3-dimensional underground load-bearing structures.

Keywords: Salt Cavities, Cavern Abandonment, Rock Mechanics, Salt Properties, Cavern Design, Hydromechanical Interaction, Infiltration, Laboratory Testing, Numerical Simulation, Field Test, Back Analysis