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Geotechnical experiences in flooding underground openings in salt formations

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Abstract

Underground openings in salt formations (e.g. mines or caverns) represent significant challenges to engineers in charge of ensuring their long term stability, not only during operation but also during abandonment. Controlling key factors are (1) state of stress, (2) dilatancy, healing and creep properties of the salt, (3) geometry of underground openings, (4) lithologic heterogeneity and (5) rock support after excavation (back filling resp. fluid pressure). After life time the flooding of caverns and mines with brine is currently the most promising technique for final closure.

However, due to stress redistribution during excavation and operation a disturbed or damaged zone (EDZ) is expected in the surrounding salt contour, respectively in the load bearing pillar and beam systems. Micro- and macro-fracturing will cause an increase in permeability by increasing the connected porosity. Inflow of fluids into dilated and damaged rock portions may significantly affect the overall rock mechanical stability by reducing the effective pressure and/or lowering the friction. Therefore, understanding of these complex processes is of major importance e.g. for awarding of closure concept by responsible authorities.

In this paper, results of underground observations regarding damage and solution effects in salt will be reported. Furthermore, the actual state of knowledge obtained at IfG Leipzig for quantifying interactions of host rock properties and penetrating brine is demonstrated. Over the last decade we have performed an extensive laboratory program for different saliniferous host rocks focusing on rock mechanical properties (e.g. strength, creep) during application of various pore fluid pressures (gas, brine) including hydraulic measurements (dilatancy, permeability and hydraulic frac behavior).

Recently, IfG Leipzig developed a modeling procedure based on difference element computer code, e.g. FLAC, to solve the relationships between underground opening size and shape, in-situ stresses, and the constitutive laws (material models) of the host salt formation, which comprises the structure. It will be demonstrated exemplarily that the software has been validated with in-situ experiments at various scales.

Finally, based on concrete site studies the fundamental demands for geotechnical safety criteria of flooded underground openings with consideration of site- and scale-related permeation effects will be discussed.