Saf. Nucl. Waste Disposal, 2, 167–167, 2023
https://doi.org/10.5194/sand-2-167-2023

SaND
Safety of Nuclear Waste Disposal
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State of the art of hydraulic packer testing in clay rocks in the Swiss national radioactive waste disposal program

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Received: 3 April 2023 – Revised: 31 May 2023 – Accepted: 5 June 2023 – Published: 6 September 2023

Abstract. To provide input for site selection and the safety case for deep geological repositories for radioactive waste, Nagra has drilled a series of deep boreholes in northern Switzerland. As part of the hydrogeological characterization of this exploratory drilling campaign, hydraulic packer tests in the sedimentary rocks were carried out under the supervision of Nagra, in depths from 300 to 1130 m b.g.l. (below ground level).

Single or straddle-packer hydraulic tests were conducted in different low-permeability rocks. The hydraulic testing equipment used was specially designed to reduce uncertainty associated with the low-permeability testing conditions and included a downhole hydraulic shut-in valve (DHSIV), a hydraulic piston, a probe carrier, and inflatable packer(s). Pressure and temperature are monitored with sensors connected to the bottom of the borehole, the test interval, the annulus above the upper packer, and the test tubing above the DHSIV.

Hydraulic test sequences consisted of multiple withdrawal and shut-in phases. Test phases started with a compliance phase to allow some of the pressure and temperature transients caused by tool installation and packer inflation to dissipate, followed by a pressure static recovery phase to allow the test interval pressure to establish a recovery trend after being isolated. In general, in the low-permeability formations the active test sequence consisted of a pulse withdrawal performed using a hydraulically operated piston displacing a precisely defined volume, a slug withdrawal, and lastly a slug-withdrawal shut-in phase.

The pressure data collected during the hydraulic tests were analyzed using the well-test simulator nSIGHTS®. The use of a numerical model is necessary for the analyses of the tests in low-permeability rocks as borehole history and temperature equilibration during the test can have a significant impact on test responses. Analyses started with the definition of a borehole-formation conceptual flow model based on geological information and interpretation of diagnostic plots. Input model parameters composed of non-fitting parameters and fitting parameters are defined. Preliminary automated calibrations are performed to identify the appropriate conceptual model and obtain baseline estimates of the fitting parameters for each tested interval. Perturbation analyses entailing hundreds to thousands of optimizations are performed to obtain the final best-fit parameter values and the corresponding uncertainty ranges.

Our presentation will give an overview on methodologies and workflows with emphasis on the numerical design and analysis techniques applied to the hydraulic packer tests performed. The applied methodology provided high-quality results and reliable estimates of the hydraulic conductivities in the low-permeability rocks. The results from the hydraulic packer tests will be presented, and implications for further research by Nagra will be discussed.

Published by Copernicus Publications on behalf of the Federal Office for the Safety of Nuclear Waste Management (BASE).