

In-situ stress via dry reopening test in the
Bedretto Underground Laboratory (BUL)

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Introduction:

Geothermal energy is a source of clean energy. In Switzerland, it has been seen as an energy source to be exploited as part of its 2050 energy strategy contributing to the 7%. However, as it is an energy source not well known worldwide and there are some uncertainties about the seismic risks while its exploitation, there is great opposition from part of the population in Switzerland. As a consequence of all of that since 2017, in Ticino, The Bedretto Underground Laboratory for Geoenergies was settled inside the Bedretto tunnel (Fig. 1) (access to the Furka tunnel).

As part of the ground reconnaissance, a campaign of several test took place. The objective of the overall test is to see the reaction of the host rock, the Granite Rotondo, under a high-pressure injection of water, in parallel very precise measurements of the seismicity will be done. This phase is of great importance to prove the safety of the exploitation of this energy as the conditions in the lab are close to reality. As part of a successful study, the good knowledge and the precise mapping of the in-situ stress field, the rock mass is characterised by.

This project is about the dry reopening test (DRT) which is used to measure the reopen pressure P_r and to estimate one of the components of the in-situ stress. The maximum horizontal in-situ stress (S_{Hmax})

In addition, the packer material behaviour was analysed. The packer is made of an hyper-elastic material and has some influence in the DRT because the displacement is not constant in all the directions.

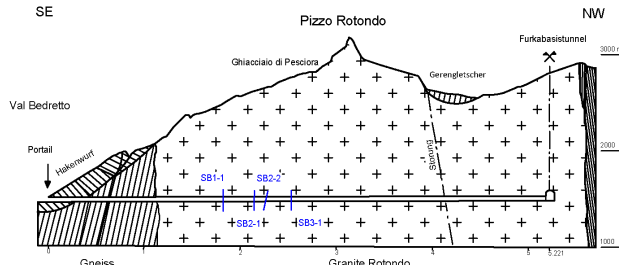


Figure 1: Geological section of the BUL (Keller, F. Schneider, T. R., 1982)

Methodology:

The setup used for the DRT is the same as for the hydraulic fracturing test (HFT). In contrast to the HFT, in the DRT the liquid is injected inside the packer only, there is no liquid penetration into the borehole or into the pre-existing fractures. The bottom packer is placed at the same depth at which the HFT was carried out (Fig. 2) shows. In the HFT a fracture was created.

This test was applied in the SB1-1, SB2-1, SB2-2, and SB3-1 boreholes, see Figure 1. Each borehole has a final depth between 30 to 40 m and a diameter of 101 mm. The SB2-2 borehole has an inclination of 20° the rest of them are vertical.

The P_r is obtained directly the recorded data by analysing the pressure-volume curve by fitting a parabola function to it [1]

The S_{Hmax} is obtained with the following equation which comes from one of the Kirsch equations [2] when the fluid does not penetrate the fracture and the fracture is long enough.

$$S_{Hmax} = 3 * S_{Hmin} - P_r - P_p + T_0$$

Where, T_0 , the tensile strength, is zero because there was a pre-existing fracture, S_{Hmin} , the minimum horizontal in-situ stress came from the HFT, and, P_p , the pore pressure that was measured in place.

Packer test:

The packer in which the fluid injected, is made of rubber, it has also an internal steel layer and its global mechanical response is similar to a hyper-elastic material that means that it has large deformations and has a non-linear behaviour [3]. As part of the project the analytical solution for this hyper-elastic material was proposed applying the Neo-Hookean model applying the Neo-Hookean model, Ogden type [4] in order to find its properties.

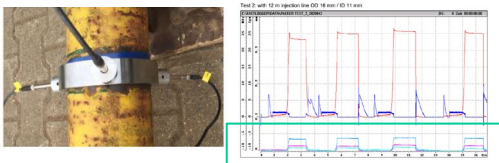


Figure 3: Mechanical model of the packer test

In parallel a packer test was done, (Fig. 3), in the lab. The measurements shows in the displacement – time curve that the displacement is different in the three directions where the captors were applied.

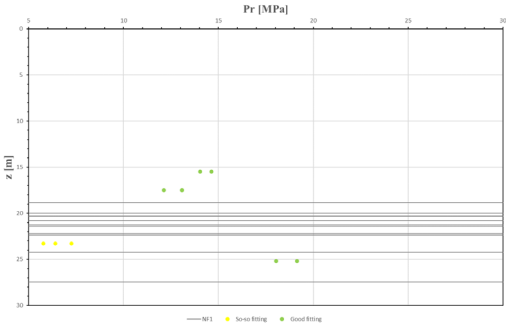
Results and discussion – Reopen pressure:

The results of the DRT compared with the HFT in the boreholes SB1-1, SB2-1, SB2-2 and SB3-1 show that the reopen pressure (P_r) estimated in the HFT is bigger than in the DRT, around 60 % of the tests. In those cases, where the reopen pressure estimated with the DRT is larger than the one estimated from the HFT, probably a fracture was created in the first cycle that usually happens during a Sleeve test [5]. An example for this is the SB1-1 borehole, where a new fracture was created in the first cycle at 12.6 and at 24 m depth. The reopen pressure is influenced by the natural fractures (NF), in those zones the value of the reopen pressure drastically drops (Fig. 4).

Figure 4:

Reopen pressure estimated with the DRT in the vertical borehole SB2-1.

green: exactly values where the parabola was well fitted, in yellow: estimated values, where the parabola was almost well fitted horizontal lines: natural fractures



Results and discussion – S_{Hmax} stress:

From the analyses of the four boreholes together. It was found that the S_{Hmax} in the SB3-1 from 12 to 20 m is considerably higher than of the other boreholes at an equivalent depth.

it was observed that the S_{Hmax} is influenced by the natural fractures. The value of S_{Hmax} increased until the fracture zone was reached (red zone), (Fig. 6) then the increase stops/drops around the fracture zone, after that the S_{Hmax} increases again.

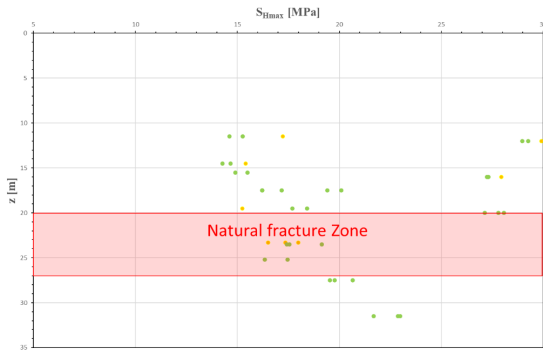


Figure 5:

Maximum horizontal stress values of the all boreholes estimated with the DRT.

Green values: come from the exactly values where the parabola was well fitted, yellow values: com from the estimated values, where the parabola was almost well fitted horizontal lines: natural fractures

Conclusion:

The DRT contributes to the determination of the S_{Hmax} of the in-situ stress field with the measurement of the fracture reopening pressure P_r . The other components of the in-situ stress field are obtained with the HFT and by the overburden method.

The reopen pressure estimated with the DRT is good, because there is no liquid influence.

The reopen pressure between depth 12m-31m from 3 vertical boreholes varied between 6.40MPa and 20.63MPa. The S_{Hmax} between depth 12m-31m for all boreholes varied between 9.67MPa and 29.92MPa.

The horizontal components, S_{Hmin} and S_{Hmax} , of the in-situ stress are found with the HFT and the DRT respectively. The vertical component is measured with the overburden method.

The constants from the analytical solution for the packer test are: $k=-214.4$, $c=-4.3$ and $a_2=0.21$. Those values have to be verified with the analysis of the packer test results.

References:

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