Geophysical Research Abstracts
Vol. 21, EGU2019-4491, 2019
EGU General Assembly 2019

A new methodology to determine the shear moduli in anisotropic rocks using a single uniaxial test

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The mechanical behavior of many types of rocks is anisotropic due to their complex micro-structure. For example, rock types such as granite and gneiss exhibit anisotropy due to foliation. Enhanced geothermal systems are normally placed in crystalline basement, where these types of anisotropic rocks are likely to be present. A few methods have been proposed to determine the elastic constants of anisotropic rocks. However, these methods often determine the shear moduli indirectly, or use the Saint-Venant assumption to approximate the transverse shear modulus. In this paper, we present a methodology to determine the shear moduli directly from a simple uniaxial compression test.

We developed explicit formulae that allow the calculation of the orientation of the isotropy plane, and static and dynamic values of the shear moduli from one cylindrical sample. In order to examine this development, we performed uniaxial compression tests on cylindrical specimens of granite, extracted from the underground rock laboratory in the Grimsel Test Site (GTS), Switzerland. These rock samples exhibit a clear foliation that induces anisotropy. In order to allow lateral displacement at the top of the samples, we used a modified uniaxial test configuration, where a ball-bearing plate is placed on top of the sample. Normal and shear strains were measured at different polar angles around the circumference. In addition, the lateral displacement of the ball-bearing plate was measured in two directions, allowing the determination of the isotropy plane orientation. Apart from the uniaxial test, ultrasonic measurements were conducted in order to obtain the orientation of the isotropy plane and the dynamic elastic constants.

The main outcomes of our experiments are as follows: 1) strain variations around the circumference are shown to follow the variations in the analytical formulae that are obtained for a transverse isotropy model. This indicates that transverse isotropy is a suitable model to predict the elastic response of this type of granite. 2) The orientation of the isotropy plane, determined from two independent methods, shows that the assumption of coinciding foliation plane and isotropy plane is a very good approximation. 3) The developed method proves to be accurate and efficient for determining the shear moduli directly. This method is based on only one sample, and prevents introducing errors due to heterogeneity when multiple samples are used to obtain the shear moduli. Overall, this research is considered to be an important step towards designing a standard method for the determination of the elastic constants in anisotropic rocks.