Swiss Federal Institute of Technology Zurich
Departement of Earth Sciences
NO F61, Sonnegstrasse 5, 8092 Zürich
Daniel Vogler - daniel.vogler@erdw.ethz.ch

ETH zürich

www.engineeringgeology.ethz.ch

Understanding fracture growth in 3d printed materials for applications in rock mechanics

Background Quantitative measurements of rock properties are crucial for geosciences and geotechnical engineering. Common industrial applications that require thorough investigation of rock properties include oil-, gas, and geothermal reservoirs, nuclear waste storage, tunneling, hydropower plants and landslides. The concept of crack damage thresholds, in cluding crack initiation and propagation, was discovered by early researchers studying intact rock strength [2]. These factors include; grain size differences, micro crack density and orientation, bedding planes, veins, and other aspects creating heterogeneity in the intact rock. The heterogeneous nature of rock makes the study of these influencing factors challenging since the exact sample cannot be tested with different stress paths.

Brazilian Test One of the most common tests to assess rock strength is the Brazilian test, in which a cylindrical sample is loaded from the top and bottom until a crack propagates through the sample (Figure 1). It follows a standard testing procedure (1979) governed by the International Society of Rock Mechanics (ISRM).
The rock strength as determined by the Brazilian test depends on heterogeneities in the rock, the sample size (Cylinder diameter and height), the rock type (e.g., sandstone, granite or clay) and mineralogy. The 3d printed material should develop fractures in a similar manner to those observed on natural samples.

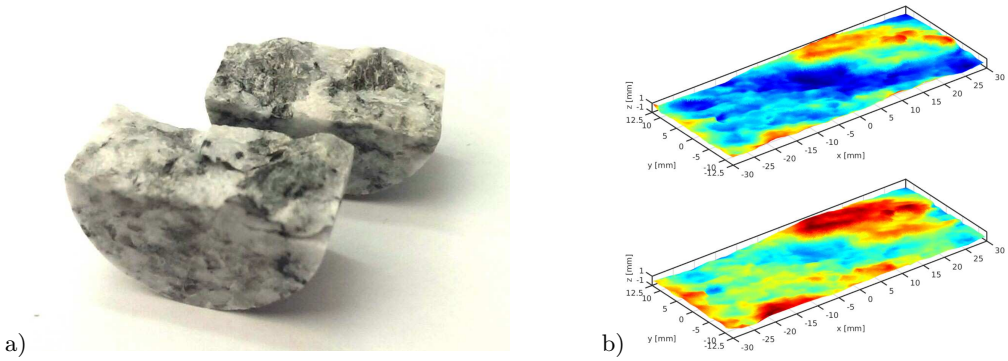

Figure 1: Two sample halves after Brazilian testing showing surface roughness where the cylinder broke in half (a), and the respective surface scans (b).

3D printing Every natural rock sample is unique, which makes it impossible to test a sample twice, for example to investigate the impact of heterogeneities on the results of the Brazilian test. 3d printing is known to utilize layering of various materials to create the object, which makes it a promising option to investigate the effect of layering (e.g., lineation) on Brazilian tests. The main objective of this project is to assess the possibility of using 3d printed samples for laboratory tests in rock mechanics and to investigate crack growth. Additional points of investigation are quantification of the influence of layering plane orientation (Figure 2) and grain size distribution within a sample on the results obtained from Brazilian tests.
For this purpose we want to manufacture samples with differing grain sizes to perform a series of tests. To date, methods used in the related geoscience industries have not been able to address the questions leading to uncertainties attached to laboratory testing of rock samples. This research project will attempt to address these questions and could lead to groundbreaking advances in geosciences.

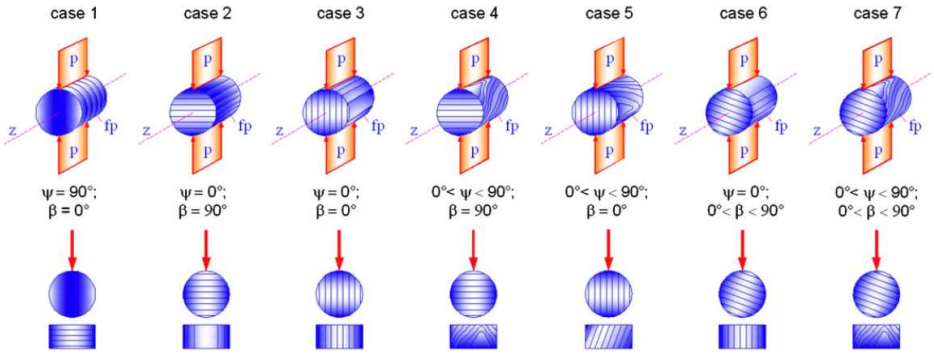

Figure 2: Example arrangement for testing rock anisotropy relative to ψ (angle between sample axis and structural plane) and β (angle between loading direction and structural plane) using Brazilian test. Combining (ψ) and (β) matrices in 15° increments a (7x7) matrix of angles. [1].

Master Thesis Tasks:

- examine the suitability of 3D printed materials at being able to simulate fracture in intact rock
- examine crack propagation and fracture surfaces in the 3d printed material (homogeneous cases) and compare it to natural and artificial fractures in rock
- examine the scale effects for application to rock mass testing

Master Thesis Goals: The goals of this thesis are to determine an appropriate 3D printed material for rock mechanics purposes, to validate the 3D printed material behavior by comparison with data in the literature on rock material.

Required Student Skills: We are looking for a student with a background in engineering or natural sciences. A background in geology or rock mechanics is not necessary. The successful candidate should have basic computer skills and an interest to work with provided software. The candidate should have a willingness to work in a laboratory environment with a multi-disciplinary team of academic and industry partners on the design of a 3d printing method appropriate for use in geosciences.

Supervision:

- Dr. Matthew Perras (mperras@ethz.ch)
- Daniel Vogler (daniel.vogler@erdw.ethz.ch)

References

[1] Dinh Quoc Dan, Heinz Konietzky, and Martin Herbst. Brazilian tensile strength tests on some anisotropic rocks. *International Journal of Rock Mechanics and Mining Sciences*, 58:1 – 7, 2013. ISSN 1365-1609.

[2] J. C. Jaeger and E. R. Hoskins. Rock failure under the confined brazilian test. *Journal of Geophysical Research*, 71 (10):2651–2659, 1966. ISSN 2156-2202.