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The onset of dilatancy in rocks

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The onset of dilatancy determines the start of critical fracture growth in rocks under increasing load. For various applications such as the construction of nuclear repositories or dams, a quantitative comprehensive knowledge on the critical conditions leading to dilatancy is required.

Thus, it is important to determine the parameters, which control the dilatant behaviour of rocks, and to analyse their interactions.

We conducted a series of undrained triaxial experiments on two consolidated, fully saturated Opalinus Clay samples from the Mont Terri underground research lab and one sample of Bunter Sandstone from southern Lower Saxony. By testing only a few samples but them extensively, we avoid that the natural material heterogeneity among multiple samples affected our results. Here we show that our approach allows identifying new correlations between different parameters with surprising clarity.

During the experiments, which can take years, the samples are repeatedly exposed to increases in differential stress (σ_1 -σ_3) into the dilatant regime but always well below the point of failure. This we achieve by monitoring the pore pressure during the increase in differential stress. The onset of dilatancy becomes visible as clear drop in pore pressure with increasing differential stress.

In addition to the detection of the onset of dilatancy via the pore pressure evolution, pressure diffusion experiments are performed to determine the onset of dilatancy. For this, in the dilatant regime, the differential stress is kept constant and the pore pressure on one side of the sample is de- and increased repeatedly, while the reaction of the pore pressure on the other side of the sample is monitored. With the pore pressure pulse diffusing though our sample specimen, this controlled pore pressure variation induces a transition between dilatant and subdilatant regimes at constant differential stress.

The values for the onset of dilatancy derived by these two methods permit a comprehensive analysis of the dilatant behaviour not only of the Opalinus Clay samples, but also of the Bunter Sandstone sample. Our results show that dilatant behaviour of the tested materials is not governed by only one parameter but by an intricate interplay of several parameters. Consequently, the development of an equation of state for the dilatant behaviour of different types of rock is achievable. However, due to the multiple parameter dependencies, it will be a time-consuming undertaking.