Initial insights into progressive failure during relaxation of Herrnholz granite subjected to three-point bending

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The propagation of fractures through intact rock under constant or reducing load conditions is known as static fatigue. This phenomena controls the progression of failure events in both natural rock environments (i.e. alpine rock slopes), and engineered settings (e.g. dam abutments, tunnels, and underground nuclear waste storage facilities). The physics of such progressive crack growth is, however, not captured in traditional rock mechanical analyses, making the prediction of long-term behaviour of bedrock in such settings complicated. Here, we presents results from single edge notch bending (SENB) tests undertaken on 400 × 90 × 90 mm prisms of Herrnholz granite subjected to alternating phases of loading at constant displacement rate, followed by load relaxation under constant displacement. These tests were undertaken in the new Rock Physics and Mechanics Lab at ETH Zurich, and provide new insight into the time-dependant behaviour of a fine-grained granite subjected to constant or reducing load conditions.

Four samples were tested in the SENB configuration, for which the first two were loaded to failure under load-point displacement (piston) control at a rate of 1 μm/s. This provided an indication of the peak strength and fracture toughness of the Herrnholz granite. The next two samples were subjected to staged loading increases (ranging from 50% to 98% of the average peak load) with load-point displacement maintained for up to 30 minutes between each load stage. Results demonstrate an exceptionally consistent failure load of 14.54 kN, ± 0.18 kN, suggesting a (theoretical) average fracture toughness of 1.82 MPa $m^{1/2}$.

Progressive failure characteristics during the load relaxation phase of the two staged tests were observed through an attached crack mouth opening displacement sensor, and digital image correlation. When loaded to between 50% and 90% of the peak load, crack mouth opening rates reduced to around 1% of the rate at the initiation of the hold period (10^{-4} mm/s) within 10 to 20 minutes. However, when the displacement was held at 98% of the peak, the creep rate demonstrated an acceleration toward failure as the load dropped by 5% over a four-minute interval.

Ongoing tests planned for more than 100 similar specimens are expected to provide data to constrain the physical properties controlling sub-critical cracking in Herrnholz granite, and the response of critically stressed cracks to changes in imposed environmental conditions. This unique dataset will provide much-needed insight into the long-term behaviour of natural and engineered rock sites.