Acoustic emission observation during staged loading and relaxation of Herrnholz granite subjected to three-point bending

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Time-dependent fracture propagation at sub-critical crack tip stress intensities known as subcritical crack growth (SCG), is gaining increasing attention, as it is seen to be the next step required to understand of the precursory phase and triggered failure of catastrophic geohazards. In particular, tensile fractures, in which rupture propagates along a plane perpendicular to the applied tensile stress can be observed in various engineering projects (e.g. hydraulic fracturing and underground excavations), and natural disasters (e.g. landslides). One of the major challenges is to figure out what controls the SCG mechanism.

Acoustic emissions (AE) are elastic waves that are emitted from brittle rock caused by microcracks and can provide valuable physical insights behind SCG. However, a number of researches indicate that no or very low AE activity is detected during SCG as cracks propagate with low energy release rate. To have a deeper understanding of AE activity during SCG, we studied AE signals of Herrnholz granite under single edge notch bending (SENB) tests using a combined AE setup under room environment conditions. Two sets of AE sensors from Physical Acoustic Corporation (PAC), and KRNBB-PC sensors with different sensitivities (PAC: ~1 V/nm, KRNBB-PC: ~0.015 V/nm), contact area (PAC: face contact, KRNBB-PC: point contact) and frequency ranges (PAC: resonant, KRNBB-PC: flat, wideband) were attached to a 400 × 90 × 90 mm SENB specimen.

For the 1st and 2nd stages, the rock specimen was loaded under constant load-point displacement rate of 1 µm/s until 50% and 60% of the estimated peak load (from preliminary testing results) and then went through stress relaxation under constant displacement for 10 minutes, respectively. Then the specimen was loaded again until 91% of the peak load and 20 minutes under stress relaxation (3rd stage). The staged loading under constant displacement rate and then stress relaxation cycles was repeated progressively up to the 98% of the peak load where the specimen failed within 4 minutes.

PAC sensors, with higher sensitivity, could detect more signals (620 events occurred within 222 s) and show that crack numbers increase logarithmically after the 4th staged loading (98% of the estimated peak load), while most signals from KRNBB-PC sensor are recorded in the last 10 seconds or completely after the failure. Though they detect fewer AEs, KRNBB-PC sensors are still useful as they have a wideband frequency range and therefore can provide information on energy partitioning. The 3D AE locations from KRNBB-PC sensors show that most microcracks distributed within an apparent zone of nearly 4 cm width during the last relaxation stage, which are centered around the notch but relatively scattered probably caused by anisotropic velocity model, signal to noise ratio, sensor locations, etc. However, they have similar trends with the results of other techniques such as digital image correlation (DIC). In the next step, improvements will be made in the source locations and other pieces of information related to source mechanisms, crack direction, etc. will be studied.

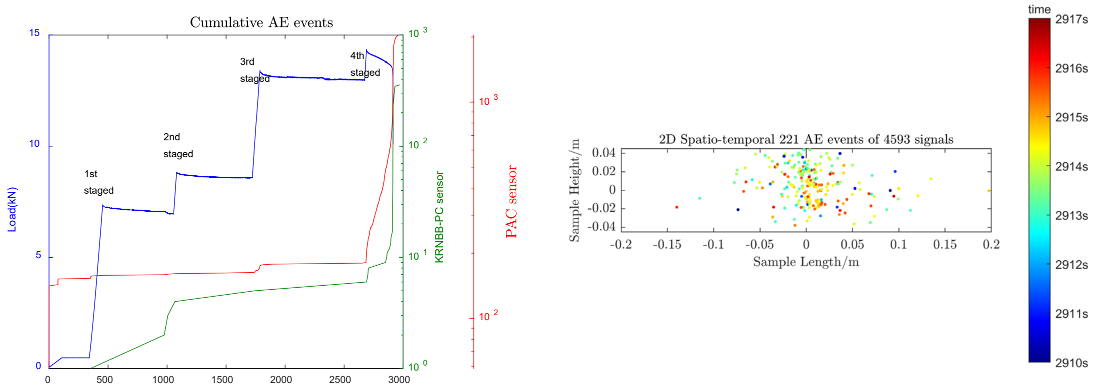

Figure 1. AE results from a SENB test. *Left*: loading data and cumulative AE events from 2 different AE sensors. *Right*: 2D AE locations from KRNBB-PC sensors during the last relaxation stage.

The initial results of this study demonstrated that resonant sensors can detect much more crack events than their broadband counterparts during progressive failure of rocks, and therefore observe earlier precursors before the catastrophic failure. This study will continue by conducting creep tests on more than 100 similar specimens under different mechanical and environmental conditions (temperature, humidity, surface water, etc.) to better understand the long-term behavior of natural and engineering settings.