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Numerical Simulation of Rock Fracturing under Laboratory True-Triaxial Stress Conditions

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A True-triaxial test (TTT) also known as polyaxial test was carried out on saturated Fontainebleau sandstone to elevate our knowledge about the role of the intermediate principal stress on deformation, fracturing and failure patterns of the rock using acoustic emission (AE) monitoring. The induced AE activities were studied by location of the AE events and mapping them on the captured features in the post-mortem CT scan images of the failed sample. The time-lapse monitoring of the velocity structure and AE activity in the sample portrayed a deformational path which led to propagation of fractures and formation of failure patterns in the rock. Having these experimental results, we aimed at running a numerical model of our true-triaxial testing system using an Itasca software based on three-dimensional explicit finite-difference method called FLAC3D. The loads were applied at the end of each platen while the steel platens transferred the stress to the surface of the cubic specimen. In order to simulate the failure, randomly distributed strength demonstrated by Mohr-Columb failure criterion was implemented in the spatial elements of the model representing the random distribution of the micro-cracks. During the experiment, pseudo-boundary surfaces were formed along the minimum and intermediate principal stress axes in the rock due to non-uniform distribution of stress as a result of geometrical constraints including the corner effects and friction on the platen-rock surfaces. Both the real AE data as well as the numerical simulation verified that coalescence of micro-cracks mainly occurred around these pseudo-boundaries with highest stress gradients as well as highest velocity gradients in the rock specimen and formed curvi-planar fractures. The rock specimen strength and brittleness in the macro-scale was also obtained from the stress-strain curve which was consistent with the experimental laboratory measurements. Eventually, the failure of the rock specimen was simulated at the final stages of the experiment at higher effective stresses where an M-shaped form of through-going fractures was developed and their spatial orientations and angles were measured under various polyaxial loading conditions. This study enhances our understanding about the nature of initiation and propagation of fractures under true-triaxial stress states.