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Reducing boundary effects during True Triaxial loading of rocks

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Even though stresses in the crust are triaxial (□□1>□□2>□□3) the overwhelming majority of rock deformation experiments are conducted under axisymmetric (or conventional triaxial) loading (□□1>□□2=□□3). This configuration disregards the effect of □□2 on the physical and deformation properties of rocks, thus complicating and degrading the extrapolation of results to natural crustal conditions. A True Triaxial loading configuration is necessary to overcome this simplification, however, these improvements in addressing real crustal conditions come at a cost, which is the challenging boundary conditions that arise from having six loading rams rather than just two. Two main loading boundary effects can severely impact the stress distribution and failure mechanism of samples deformed in a True Triaxial Apparatus (TTA): 1) the end friction effect caused by the stiffness contrast between the rock sample and the metal loading platens, and 2) the unstressed sample edges resulting from the requirement that loading platens must necessarily be slightly smaller than the rock specimen. Managing and reducing these boundary effects is fundamental for obtaining accurate and representative data from true triaxial experiments, and for the further development of these apparatuses.

A novel TTA developed in the UCL Rock & Ice Physics Laboratory was designed to subject cubic or cuboid rock samples to truly triaxial stresses through the independent control of six loading rams. The apparatus is equipped with a confining and pore pressure system that allows for the deformation of saturated samples whilst simultaneously measuring permeability along the three axes. A suite of Finite Element Method (FEM) models was implemented to evaluate the parameters that minimize loading boundary effects in UCL's TTA for a 50 mm edge-length cubic sample of sandstone. Our results indicate that using aluminum loading platens (□□□□□□□□□□□□□□/□□□□□□□□□□□□□□=0.4 reduces the end friction effect by a factor of two compared to using steel platens (□□□□□□□□□□□□□□/□□□□□□□□□□□□□□=0.17). In addition, we find that elevated confining pressure significan reduces the stress concentration produced by unstressed edges. Specifically, a confining pressure of 10 MPa eliminates tensile stresses at the sample corners. These results are currently being implemented into the experimental protocol and execution in UCL's TTA in order to ensure that we obtain reliable true triaxial data. However, these observations are generic and could therefore contribute to improved development and operation of true triaxial loading systems generally.