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A Preliminary Analysis Of Edge-Effects In True-Triaxially Deformed Cubic Darley Dale Sandstone Samples

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ABSTRACT

Stresses acting on the rock bodies which result in their deformations are anisotropic in nature. Processes of deformation of rocks and minerals in the Earth's crust and mantle can be studied in the laboratory by subjecting samples to a variety of stress states in combination with high ambient pressures and temperatures (Heard et al.,1986). A novel true-triaxial loading apparatus can be used to accurately replicate crustal stress states and anisotropic deformation. Edge effects result from frictional constraints introduced between the loading ram, platen and sample faces during orthogonal loading(Alexeev et al.,2004). The frictional constraint is introduced because the rock tends to dilate in opposing direction to the maximum applied stress. However, this expansion tendency is hindered by other loading rams and face platens to which the sample is in direct contact. This pheonomenon potentially creates deformation on sample edges and corners which are different from those in middle portions of sample. This study aims to test the techniques that examine and identify the severity of edge effects in cubic samples of Carboniferous Darley Dale Sandstone, after true-triaxial deformation has been applied.

Samples were shaped into cubes with 50mm edge and subjected to deformation under true-triaxial conditions with σ3 held at 4MPa, with σ1 and σ2 adjusted throughout and maximum differential stress$\Delta\sigma$ = 80MPa(Stuart et al.,1993).To analyze potential edge effects produced during these tests, four techniques viz. Ultrasonic wave velocities, Microstructural observation in thin sections, Steady-state permeability, and Porosity were used as they reveal sensitivity to crack populations developed in rocks via deformations. Measurements were made using these techniques over different parts of the sample to distinguish differences from edges of the sample to the middle.

The velocity trends of both compression(P) waves and shear (S) waves showed clear variation from edges to the middle portion of sample. Measurements taken normal to the maximum(σ1) and intermediate(σ2) stress directions indicated an increase in velocities in the middle of the sample whereas the opposite situation was found in the direction normal to minimum principal stress direction(σ3). SEM(Scanning Electron Microscope) images of the samples were used to observe microcrack density and crack orientations whose analysis was done using MATLAB. The observations showed no significant changes in the trend of crack density and orientation from edges to middle portion of the sample. Steady-state permeability measurements were made from a cylindrical core of 50mm length, 20mm diameter cut through the middle of a sample. The permeability of this sample at an effective pressure of 10Mpa, was 3.92x10-15m2. The core was then cut to make three cylindrical sub-samples representing two edges and a middle section. The permeability values for these sub-samples showed negligibly small variation. Total porosity of dried sub-samples was measured with He-Pycnometer. Total porosity values at edges were 17.50% and 17.27% whereas the value rose to 18.48% in middle, showing more than 5% increase.

To conclude, results obtained from the experiments suggest that there exists a potential of edge-effects for rocks deformed in true-triaxial testing. Velocity trends of ultrasonic waves show differential crack closure in different portions of sample. Porosity values suggest that more cracks occur in the middle of sample. Permeability and microstructural analysis is inconclusive in showing any difference between edges and middle of sample. For future works, two ways to resolve problems on confined edges in true-triaxial testing of rock samples are suggested. The first would be a low-friction membrane inserted between the sample-face and loading piston, so as to minimize the frictional constraint and lower the edge-effects. Additionally, the loading piston can be made of a material having similar elastic properties to the rocks being tested.