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Investigation of the permeability of coal fractures and cleats on multiple scales

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Coal is characterised by its unique microstructure made up of a porous matrix intersected by a network of face and butt cleats. Together with large-scale fractures and faults, these small-scale cleats provide the principal source of permeability for groundwater and gas flow within a coal seam. On the example of a Bowen Basin coal, the permeability across scales has been investigated using field studies, laboratory work, and numerical modelling.

Field work has been undertaken at the Hail Creek Coal Mine in Central Queensland, Australia. A Heat Pulse Flow Meter, a downhole wireline tool, was utilised to test for permeability of macro-scale (metres to kilometres) fractures frequently associated with fault structures intersecting the coal measures at the mine site. Coal samples were taken for subsequent laboratory work to cover the meso-scale (centimetres to decimetres). The coal samples taken at two coal seams, the Elphinstone and the Hynds seam, were tested for permeability in a triaxial cell using the constant head test method. Based on Computer Tomography scans of the coal, the samples were numerically reconstructed to allow for investigations on the micro-scale (millimetres to centimetres). A Lattice-Boltzmann-based code was utilised for simulating fluid flow and estimating permeabilities within the three-dimensional cleat network on a range of subsample volumes. The correlations of results across scales were investigated and up-scaled to the Representative Element Volume using a power-averaging approach.

Permeability heterogeneities are observed at each scale. Using the average numerical data, a trend is found that shows an increase in permeability with an increase in scale. The numerical investigation of the permeability for different subsample volumes over a micro-scale found average permeability values in the range of 0.38 mD to 6.77 mD for the Elphinstone coal, and 0.21 mD to 9.01 mD for the Hynds coal. The laboratory values, investigating permeability over a meso-scale, span 0.023 mD to 1.408 mD for the Elphinstone seam, and 0.011 mD to 20.62 mD for the Hynds seam. Finally, the largest range in permeability has been obtained from the field work, which measured permeability at the macro-scale. These permeability values vary between 0.17 mD and 70.46 mD for the Elphinstone seam, and between 3.04 mD and 88.31 mD for the Hynds seam.

The variation between the field work and laboratory results shows that the permeability of coal is governed by two main systems: coal cleats and coal fractures. Laboratory values are representing the bulk measurement of the micro-scale cleat permeability, while field-scale values represent the macro-scale at which permeabilities are governed by larger coal fractures. To capture the heterogeneity of permeability of coal within this dual scale system, investigations have, therefore, to be focused on the scale of the intended use of the respective study.

This study has been undertaken within the framework of the PhD project ‘Multi-scale permeability of coal fractures and cleats’ finalized by the presenter at the School of Civil Engineering, University of Queensland, Australia, in 2017.