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Percolation and permeability of heterogeneous fracture networks

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Natural fracture fields are almost necessarily heterogeneous with a fracture density varying with space. Two classes of variations are quite frequent. In the first one, the fracture density is decreasing from a given surface; the fracture density is usually (but not always see [1]) an exponential function of depth as it has been shown by many measurements. Another important example of such an exponential decrease consists of the Excavated Damaged Zone (EDZ) which is created by the excavation process of a gallery [2,3]. In the second one, the fracture density undergoes some local random variations around an average value.
This presentation is mostly focused on the first class and numerical samples are generated with an exponentially decreasing density from a given plane surface. Their percolation status and hydraulic transmissivity can be calculated by the numerical codes which are detailed in [4]. Percolation is determined by a pseudo diffusion algorithm. Flow determination necessitates the meshing of the fracture networks and the discretisation of the Darcy equation by a finite volume technique; the resulting linear system is solved by a conjugate gradient algorithm. Only the flow properties of the EDZ along the directions which are parallel to the wall are of interest when a pressure gradient parallel to the wall is applied. The transmissivity T which relates the total flow rate per unit width Q along the wall through the whole fractured medium to the pressure gradient grad p, is defined by Q = − T grad p/mu where mu is the fluid viscosity.
The percolation status and hydraulic transmissivity are systematically determined for a wide range of decay lengths and anisotropy parameters. They can be modeled by comparison with anisotropic fracture networks with a constant density.
A heuristic power-law model is proposed which accurately describes the results for the percolation threshold over the whole investigated range of heterogeneity and anisotropy.
Then, the data for transmissivity are presented. A simple parallel flow model is introduced. The flow properties of the medium vary with the distance z from the wall. However, the macroscopic pressure gradient does not depend on z, and the flow lines are in average parallel to the wall. Hence, the overall transmissivity is tentatively estimated by a parallel flow model, where a layer at depth z behaves as a fractured medium with uniform properties corresponding to the state at this position in the medium. It yields an explicit analytical expression for the transmissivity as a function of the heterogeneity and anisotropy parameters, and it successfully accounts for all the numerical data.
Graphical tools are provided from which first estimates can be quickly and easily obtained.
A short overview of the second class of heterogeneous media will be given.
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