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Three-dimensional fracture density variability of fractured rock mass: analytical solutions for Poissonian networks

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We address the issue of the density variability of three-dimensional fracture networks with Poissonian (spatially random) positions and power-law size distributions. This statistical distribution has been widely used to model fracture networks in crystalline environments in order to derive the permeability and mechanical properties of rocks. One of the issues for this purpose is the difficulty in accessing three-dimensional data, which requires to deal with well (1D) or outcrop (2D) fracture density measurement. Quantifying the three-dimensional fracture density variability at any scale is a key point for risk analysis in many industrial projects such as deep waste disposal, among others. We propose here an analytical framework to predict the three-dimensional fracture density variability of fracture networks from lower dimension measurements. These analytical solutions are validated through numerical analysis on Discrete Fracture Networks models. We show that this variability is dependent of the study scale, the mean fracture density over the whole network, and the fracture size distribution. Indeed, for networks described by a power-law fracture size distribution, the higher the power-law exponent, the faster fracture density variability drops down with scale.