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Analysis of poroelastic effects on the compliance matrix of a single fracture

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Seismic waves propagating across fractures experience strong attenuation and dispersion effects. This is why the seismic method is currently considered as a key tool to remotely characterize fractured rocks. In this context, numerical simulations of seismic wave propagation in fractured media are often performed in the framework of the so-called linear slip theory. The theory describes a single fracture as an imperfectly bonded interface across which the stress components are continuous but the normal and tangential displacements are not. The corresponding displacement jumps are linearly related to the stress through a compliance matrix, which characterizes the mechanical properties of the fracture. Moreover, the background is represented by an elastic solid. However, when a seismic wave compresses a fracture embedded in a fluid-saturated porous background, it can produce significant fluid flow between the fracture and the surrounding background. This frequency-dependent fluid flow can affect significantly the solid displacement discontinuity and, thus, the compliance matrix. The aim of our work is to include these so-called poroelastic effects into the linear slip model through the development of a complex-valued, frequency-dependent compliance matrix. To this end, we model the fracture as a fully saturated thin poroelastic layer embedded between two fluid-saturated poroelastic half-spaces. Considering a plane P or S-wave incident on the fracture we numerically compute, based on the Biot's poroelastic equations, the solid displacement vector across the fracture and the mean stress tensor within the fracture. Next, we evaluate the corresponding compliance matrix by considering a linear dependence between the displacement vector and the stress tensor, which can be used in the framework of the linear slip theory. We compare the reflection and transmission coefficients obtained by our poroelastic approach with those provided by the linear slip theory using the resulting complex-valued and frequency-dependent compliances.