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# Effects of fracture contact areas on seismic attenuation due to wave-induced fluid flow

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Wave-induced fluid flow (WIFF) between fractures and the embedding matrix is considered to be a predominant seismic attenuation mechanism in fractured rocks. That is, due to the strong compressibility contrast between fractures and embedding matrix, seismic waves induce strong fluid pressure gradients, followed by local fluid flow between such regions, which in turn produces significant energy dissipation. Natural fractures can be conceptualized as two surfaces in partial contact, containing very soft and highly permeable material in the inner region. It is known that the characteristics of the fracture contact areas control the mechanical properties of the rock sample, since as the contact area increases, the fracture becomes stiffer. Correspondingly, the detailed characteristics of the contact area of fractures are expected to play a major role in WIFF-related attenuation. To study this topic, we consider a simple model consisting of a horizontal fracture located at the center of a porous rock sample and represented by a number of rectangular cracks of constant height separated by contact areas. The cracks are modelled as highly compliant, porous, and permeable heterogeneities, which are hydraulically connected to the background material. We include a number of rectangular regions of background material separating the cracks, which represent the presence of contact areas of the fracture. In order to estimate the WIFF effects, we apply numerical oscillatory relaxation tests based on the quasi-static poro-elastic equations. The equivalent undrained, complex plane-wave modulus, which allows to estimate seismic attenuation and velocity dispersion for the vertical direction of propagation, is expressed in terms of the imposed displacement and the resulting average vertical stress at the top boundary. In order to explore the effects of the presence of fracture contact areas on WIFF effects, we perform an exhaustive sensitivity analysis considering different characteristics for the regions of contact. This study enabled us to observe that in the case of regular distributions of contact areas seismic attenuation and dispersion levels increase with decreasing size or increasing separation of the contact areas. In addition, we corroborated that for the same fraction of contact area, seismic attenuation and dispersion are weaker for regular distributions of contact areas and stronger when they are located within a narrow cluster. Our numerical approach also allowed us to explore the vertical solid displacement gap across fractures. We found that this parameter is strongly affected by the geometrical details of the fracture contact areas and turned out to be complex-valued and frequency-dependent due to WIFF effects. Finally, using laboratory measurements of changes in fracture contact area as a function of the applied stress, we proposed a model illustrating the effects related to the evolution of the contact area with increasing stress. The corresponding results suggest that seismic attenuation and phase velocity may constitute useful attributes to extract information on the prevailing effective stress of fractured media.