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Effect of normal and shear loading on the hydraulic transport properties of calcite bearing faults with customized roughness.

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Understanding fluid flow in rough fractures is of high importance to large scale geologic processes and to most anthropogenic geo-energy activities. Here, we conducted fluid transport experiments on Carrara marble fractures with a novel customized surface topography. Transmissivity measurements were conducted under normal stresses from 20 to 50 MPa and shear stresses from 0 to 30 MPa. An open-source numerical procedure was developed to simulate normal contact and fluid flow through fractures with complex geometries. It was validated towards experiments. Using it, we isolated the effects of roughness parameters on fracture fluid flow. Under normal loading, we find that i) the transmissivity decreases with normal loading and is strongly dependent on fault surface geometry ii) the standard deviation of heights (hrms) and macroscopic wavelength of the surface asperities control fracture transmissivity. Transmissivity evolution is non-monotonic, with more than 4 orders of magnitude difference for small variations of macroscopic wavelength and roughness. Reversible elastic shear loading has little effect on transmissivity, it can increase or decrease depending on contact geometry and overall stress state on the fault. Irreversible shear displacement (up to 1 mm offset) slightly decreases transmissivity and its variation with irreversible shear displacements can be predicted numerically and geometrically at low normal stress only. Finally, irreversible changes in surface roughness (plasticity and wear) due to shear displacement result in a permanent decrease of transmissivity when decreasing differential stress. Generally, reduction of a carbonate fault's effective stress increases its transmissivity while inducing small shear displacements doesn't.