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Channel formation in gouges and grains due to seeping fluid: overpressurization and depressurization dynamics

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When fluid pressure gradients rises to sufficiently high levels in porous media, seepage forces can lead to irreversible flow of the solid matrix. This process is unstable, and leads to high permeability channel formation. This can potentially drastically affect the transport properties of confined gouges and granular materials during dynamic events, or during erosion stages. We will present here experimental and numerical results on this channel formation in confined interfaces, and the characterization of their dynamics.

Channel formation in overpressurized media

We present systems where we inject a fluid at high pressure in a porous material saturated with the same fluid, or where gravity overpressurizes the fluid in interticial pore space during granular deformation. This fluid is either a highly compressible gas (air), or an almost incompressible and viscous fluid (oil or water). We compare both situations. These porous materials are designed as analogs to real rocks, but their cohesion are lowered so that the hydrofracture process can be followed optically in the lab. The fluid is injected on the side of the material. At sufficiently high overpressures, the mobilization of grains is observed, and the formation of hydrofracture fingering patterns and transition to thin branching fractures is followed and analyzed quantitatively.

Channel formation in depressurized media

Conversely, we also study the pattern formation in the decompaction process starting from free boundaries during fluid extraction, and the formation of channels and fractures around injection chambers or gravitationally pressurized chambers. Thresholds of pressures are determined for the formation of these preferential paths. The geometry of these channels, their fractal dimension, and their growth rate as function of their wavelength (their dispersion relation), are extracted from experiments and simulations, and obtained theoretically.

This allows to obtain the growth rate of these eroding mobile channels, as function of the fluid compressibility and viscosity, of the friction properties between the solid components, and of the system dimensions.

In practice, these problems are relevant for important aspects in the formation of increased permeability networks as seen in nature and industry in granular confined layers, as fault gouges, but also e.g., in active hydrofracture in boreholes, piping/internal erosion in soils and dams, sand production in oil or water wells, and wormholes in oil sands.