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Creep of porous rocks and measurements of elastic wave velocities under different hydrous conditions

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The long-term mechanical behavior of rocks is of prime importance for many geological hazards (e.g., landslides, rock falls, and volcanoes) as well as for the stability of man-made structures (underground mines, road cuts, and open pits). In some shallow environments, rocks exist in partially saturated conditions which can evolve with time according to variations in the relative humidity hr of the atmosphere (e.g., natural slopes, open cut excavations). In underground mines, rocks are also partially saturated because of artificial ventilation. These variations in liquid saturation may have a large impact on mechanical behavior since they imply variations in capillary pressure and, depending on the porosity and on the shape of the porous network, variations in the effective stresses. Therefore, knowledge of static fatigue under saturated and partially saturated conditions is important for estimating the long-term stability of such rock structures.

Many studies have already shown that time-dependent weakening is much more important for a saturated rock than for a dry one and that the time to failure may decrease by several orders of magnitude for saturated rocks as compared to dry rocks. In addition, the weakening effect of water is more significant in long-term experiments than in short-term ones (instantaneous loading). A physical explanation for these results may be the enhancement of subcritical crack growth by stress corrosion at crack tips which is often considered to be the main cause of time-dependent behavior of rocks.

The failure of brittle rocks during compression tests is preceded by the formation, growth, and coalescence of microcracks. Elastic wave velocities are reduced due to the presence of open microcraks and fractures and may be used to monitor the progressive damage of rocks. The specific experimental setup available in our lab allows the simultaneous measurement of five velocities (with different polarizations and directions) and two directions of strains on a same sample, under uniaxial compression. Different hydrous conditions (saturated or partially saturated) are tested in all creep tests.

In this paper, we focus on the time-dependent behavior and short-term mechanical behavior of iron ore and limestone in saturated and partially saturated domains. The main outcomes of these experiments are: (i) identification of the apparent dynamic stiffness tensor from elastic wave velocity measurements; (ii) assessment of velocity anisotropy, and its evolution under uniaxial loading. This last step allows for the quantification of the intrinsic and stress-induced anisotropies, leading eventually to an estimation of the microcracks density and distribution evolutions in the rock sample under loading.