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Monitoring of damage processes in cemented granular materials with acoustic emissions and seismic velocity reduction

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Earthquakes or fault core sliding occur naturally in response to long-term deformation produced by plate tectonics. However, the way the damage or fracture process of rocks control the frictional slip is not well understood. It involves indeed materials in very different states: from granular-like materials near the shear band within the highly cracked fault core [1] to almost cohesive state in distant host rocks. To address this issue, we perform controlled laboratory experiments and new numerical simulations of damage in cemented granular materials to study the material evolution from cohesive to granular-like states under external loading. Our synthetic rocks (porous media) are made of cemented glass beads in which the packing density and the cement property (ductile or brittle) as well its content are tunable [2,3]. Two mechanical tests have been conducted: i) under oedometric load in a cylindrical cell with rigid wall; and ii) under triaxial load in a cell with elastic membrane (confined by atmospheric pressure). The fracture processes are monitored by acoustic waves, measuring the longitudinal ultrasound velocity (active detection) [4] and the acoustic emission (passive detection) [5].

More precisely, in the case (i) the fracture process is likely associated with the crack increase, spatially diffused without shear-band formation. For a rock sample cemented by a ductile bond, the damage induced by load appears likely as an anomalous deviation in the master curve of stress-strain whereas the combined acoustic detection provides a very clear evidence with an important sound velocity decrease. Upon cyclic unloading-reloading, we recover a power-law scaling of the sound velocity with the pressure similar to the law in purely granular media but with a finite velocity at vanishing pressure which depends on the residual cohesion of the damaged material. When the drop stress occurs intermittently in fractured samples cemented with brittle materials, we measure not only the sound velocity decrease but also acoustic emissions. In the case (ii) under a triaxial load, we observe the formation of shear-bands, i.e. fractures on the scale of the sample at a load much smaller than those applied in the oedometric loading (i). Again, there is a strong elastic softening (velocity decrease) [4]. Finally, we also compare these experiments with the finite-element modelling of damage and wave propagation in 2D dense cemented disk packings with various cement contents and elasto-visco-plastic properties. This numerical simulation allows to characterize the heterogeneous damage of the material at a microscopic scale.

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