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CONTINUUM MODELING OF DELAYED BREAKAGE: EXPLORING THE ROLE OF GRAIN-SCALE FRACTURE KINETICS

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Summary. Laboratory evidences indicate that granular materials under high pressures tend to exhibit time-dependent deformations. Such macroscale responses depend on various grain-scale attributes, such as the fragility of the grains, their geometry, the prevailing fracture mode, and the presence of fluids into pores and/or intra-particle flaws. This contribution presents a continuum framework aimed at incorporating the grain-scale processes that are responsible for the time-dependent compaction of multiphasic granular systems. In particular, we propose an enhancement of the Breakage Mechanics theory inspired by the analogy between the energy release rate due to the growth of microscopic grain fractures and that due to the distributed fragmentation of particles embedded in a soil matrix. For this purpose, a rate-independent Breakage model has been extended to rate-dependent processes by exploiting a thermodynamic analogy between the kinetics of grain-scale crack growth and the macroscopic creep due to delayed breakage events across a sample. Specifically, an excess entropy production term expressed as a power law function of the crack growth rate has been used to describe the time-dependent growth of a Griffith crack. A similar argument has been used to formulate a rate-dependent continuum model for crushable granular continua, thus adopting the same degree of nonlinearity for the excess entropy production term associated with the Breakage growth rate. It is shown that such hypothesis enables one to recast the model in a Perzyna-like form, with a viscous nucleus that bears resemblance to the laws typically used to model subcritical fracture processes. The capabilities of the model are eventually tested against evidences available for saturated sands, as well as for unsaturated rockfill at varying levels of relative humidity, obtaining in both cases a satisfactory agreement between model predictions and experimental data.