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Shear-enhanced (de)compaction in porous rocks

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Understanding of instantaneous and long-term compaction of porous rocks is important for reservoir engineering and Earth sciences in general. Reservoir depletion due to petroleum extraction or reservoir expansion due to prolonged injection of large volumes of fluids as in geological CCS operations lead to non-hydrostatic changes in stress conditions in the reservoir and surrounding rocks inducing noticeable shear stress components. Triaxial compression tests show that shear and volumetric deformations are interdependent resulting in shear-enhanced compaction and shear-induced dilation under short-term and long-term loading. Using a classical averaging approach, we derive a two-phase viscoelastoplastic theory to describe both rate-dependent and rate-independent deformation of porous rocks. We consider evolution of a single fluid-filled pore in a solid elastoplastic or viscoplastic matrix under combined pressure and shear loading to introduce a new cap yield surface and plastic and viscoplastic flow rules for irreversible deformations. Thus, model provides a simple description of rock behavior in a wide range of strain rates. Derived analytical expressions for effective moduli allow for easy application of the model to interpretation of experimental data and easy incorporation into numerical codes for coupled fluid flow and deformation. Our model that predicts a reduction in seismic velocity with onset of plastic deformation during loading might help understanding of such observations in terms of unrecoverable plastic deformation (e.g. grain crushing, micro-fracturing) and can be used for early detection of rock mechanical failure during field development. Model predictions compare successfully with experimental data from triaxial instantaneous and creep tests.