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Prediction of effective viscoelastoplastic rheology of porous rocks using numerical averaging with CAE Fidesys

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Understanding of instantaneous and long-term compaction of porous [1, 2] 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. The phenomenon of mutual influence of compaction and shear deformation was repeatedly reported in the literature. Dilatancy and shear-enhanced compaction of porous rocks were experimentally observed during both rate-independent (plastic) and rate-dependent (viscous) inelastic deformation. Dilatancy and shear-enhanced compaction can alter the transport properties of rocks through their influence on permeability and compaction length scale.

Effective bulk viscosity is commonly used to describe compaction driven fluid flow in porous rocks. Several effective media models were proposed to model its dependence on porosity, stress state and material parameters of the solid rock grains. They are based on the averaging of a solution obtained for a single pore in a solid matrix. Thus, interaction between pores is ignored and such models are applicable strictly speaking only to very small porosities of a few percent. In high porosity rocks, pore interaction is rather significant and can lead not only to non-linear effective rheological behavior but also to formation of zones of localized deformation such as shear bands. To address these phenomena, we develop new effective media model based on Representative Volume Element [3, 4] consisting of multiple interacting pores. To resolve stress and strain field interactions caused by the presence of multiple pores in elastoplastic matrix we use numerical simulator CAE Fidesys [5], where classical associated plastic flow law with von Mises and Tresca yield criteria are implemented. For viscoplastic rocks, correspondence principle is used. We derive 3D effective stress-strain relations for porous viscoelastoplastic rocks in a general non-hydrostatic stress field.

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