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Stabilized mixed finite elements for deformable porous media with double porosity

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Summary. Natural geomaterials such as fissured rocks and aggregated soils often exhibit a pore size distribution with two dominant pore scales, usually termed macropores and micropores. High-fidelity descriptions of these materials require an explicit treatment of the two pore regions as double porosity. We develop a finite element framework for coupled solid deformation and fluid diffusion in double porosity media that employs a thermodynamically consistent effective stress. Mixed finite elements that interpolate the solid displacement and pore pressures in the macropores and micropores are used for this purpose. In the limit of undrained deformation, the incompressibility constraint causes unstable behavior in the form of spurious pressure oscillation at the two pore scales. To circumvent this instability we develop a variant of the polynomial pressure projection technique for a twofold saddle point problem. The proposed stabilization allows the use of equal-order (linear) interpolations of the displacement and two pore pressure variables throughout the entire range of drainage condition.

Keywords: coupled problem · double porosity · effective stress · mixture theory · stabilized finite elements · twofold saddle point problem

1 Introduction

Natural geomaterials often exhibit a pore size distribution with two dominant pore scales. Examples include fissured rocks and aggregated soils. In fissured rocks the two pore scales are the fissures and matrix pores, whereas in aggregated soils they are the inter-aggregate and intra-aggregate pores. Due to the significant difference in pore sizes, the two pore regions exhibit highly contrasting hydromechanical responses. For example, fissures in rocks serve as conduits for fluid flow that can significantly influence the preferential flow patterns, whereas the pores in the matrix can also provide substantial space