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3-D MODELING OF COUPLED SUBSURFACE FLOW-STRESS BY MIXED FINITE ELEMENTS

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Summary. The accurate simulation of coupling between flow and stress in saturated porous media is a major issue in a broad variety of fields, ranging from reservoir engineering to biomechanics. The numerical solution of the governing PDEs, however, can be a difficult task mainly because of two factors: (1) the solution of the fully coupled problem involves large algebraic systems that can be severely ill-conditioned; (2) the pore pressure can be numerically unstable, the main reason being the assumption of a nearly incompressible fluid which may yield a locking phenomenon with traditional finite elements.

In the present communication an original fully coupled 3-D Mixed Finite Element (FE) model is developed with the aim at reducing the numerical oscillations of the predicted pore pressure. In the Mixed FE model the unknown variables are the elemental pressures, the nodal displacements and the element normal fluxes. Using a mixed approach for the flow equation enforces an element-wise conservative velocity field with a similar order of approximation for both pore pressure and stress. This helps stabilize the numerical solution and obtain a more accurate calculation of the fluxes, which is a basic requirement whenever a flow-stress model is coupled to an advection-diffusion equation accounting, for example, for heat transfer or contaminant transport. The fully coupled algorithm is numerically implemented using a block version of the Symmetric Quasi-Minimal Residual (SQMR) solver with an ad hoc block constraint preconditioner. The Mixed FE model is validated against Terzaghi's analytical solution and successfully tested in two large size realistic and computationally challenging applications, i.e. the consolidation of a river embankment and the Noordbergum effect due to groundwater withdrawal from a shallow confined aquifer.