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Prediction of Fluid Induced Deformation using Cavity Expansion Theory

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Abstract : Geomaterials are generally porous in nature due to the presence of discrete particles and interconnected voids. The porosity present in these geomaterials play a critical role in many engineering applications such as CO2 sequestration, well bore strengthening, enhanced oil and hydrocarbon recovery, hydraulic fracturing, and subsurface waste storage. These applications involves solid-fluid interactions, which govern the changes in the porosity which in turn affect the permeability and stiffness of the medium. Injecting fluid into the geomaterials results in permeation which exhibits small or negligible deformation of the soil skeleton followed by cavity expansion/ fingering/ fracturing (different forms of instabilities) due to the large deformation especially when the flow rate is greater than the ability of the medium to permeate the fluid. The complexity of this problem increases as the geomaterial behaves like a solid and fluid under certain conditions. Thus it is important to understand this multiphysics problem where in addition to the permeation, the elastic-plastic deformation of the soil skeleton plays a vital role during fluid injection. The phenomenon of permeation and cavity expansion in porous medium has been studied independently through extensive experimental and analytical/ numerical models. The analytical models generally use Darcy's/ diffusion equations to capture the fluid flow during permeation while elastic-plastic (Mohr-Coulomb and Modified Cam-Clay) models were used to predict the solid deformations. Hitherto, the research generally focused on modelling cavity expansion without considering the effect of injected fluid coming into the medium. Very few studies have considered the effect of injected fluid on the deformation of soil skeleton. However, the porosity changes during the fluid injection and coupled elastic-plastic deformation are not clearly understood. In this study, the phenomenon of permeation and instabilities such as cavity and finger/ fracture formation will be quantified extensively by performing experiments using a novel experimental setup in addition to utilizing image processing techniques. This experimental study will describe the fluid flow and soil deformation characteristics under different boundary conditions. Further, a well refined coupled semi-analytical model will be developed to capture the physics involved in quantifying the deformation behaviour of geomaterial during fluid injection.

Keywords : solid-fluid interaction, permeation, poroelasticity, plasticity, continuum model
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