Thermo-Poromechanics of Heated Elasto-Plastic Domains

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The topic of thermo-mechanics of fluid-saturated porous media has a variety of applications in modern environmental geomechanics problems including those that arise in the geologic disposal of heat emitting high-level nuclear fuel wastes, energy resources extraction by thermal stimulation, injection of hazardous fluids into deep earth and geologic disposal of carbon dioxide in supercritical form [1-4]. In a majority of these applications, the porous fluid-saturated is modeled as a Biot poro-elastic medium that consists of a porous elastic skeleton where the fluid transport satisfies Darcy's law [5, 6] and thermal effects take into consideration conductive processes. With most rocks that are encountered in such endeavours, this idealization is a satisfactory model. There are, however, certain geologic media, notably, clay shales for which the assumptions of purely elastic behaviour of the porous skeleton is a limitation. In such materials, the skeleton itself can undergo, damage [7], yielding and plastic failure [8] that can influence the coupled processes. This paper presents solutions to problems involving the boundary heating of a fluid saturated porous sphere and the heating of a fluid-saturated medium containing a fluid-filled cavity. In both cases analytical solutions are developed for the poroelastic case and computational models are developed for the case where the porous skeleton exhibits elasto-plasticity, governed by a Cam-Clay model. Numerical results are presented to demonstrate the role of plasticity on the development of the Mandel-Cryer signature in the pore pressure response due to thermal effects.

[1] A.P.S. Selvadurai and T.S. Nguyen, (1995) Computational modelling of isothermal consolidation of fractured media, *Computers and Geotechnics*, **17**:39-73.
[2] A.P.S. Selvadurai and A.T. Mahyari (1998) Computational modelling of steady crack extension in poroelastic media, *International Journal of Solids and Structures*, **35**: 4869-4885.
[3] A.P.S. Selvadurai (2006) Gravity-driven advective transport during deep geological disposal of contaminants, *Geophysical Research Letters*, **33**, L08408, doi: 10.1029/2006GL025944.
[4] A.P.S. Selvadurai and P.A. Selvadurai (2010) Surface permeability tests: Experiments and modelling for estimating effective permeability, *Proceedings of the Royal Society, Mathematical and Physical Sciences Series A*, **466**: 2819-2846.
[5] A.P.S. Selvadurai (2013) Caprock breach; A potential threat to geologic sequestration of CO2, Ch 5 in *Geomechanics Issues of CO2 Storage Facilities* (G. Pijaudier-Cabot and J.-M. Pereira, Ed.), John Wiley, London.
[6] A.P.S. Selvadurai (2012) Fluid leakage through fractures in an impervious caprock embedded between two geologic aquifers, *Advances in Water Resources*, **41**: 76-83.
[7] A.P.S. Selvadurai (2004) Stationary damage modelling of poroelastic contact, International *Journal of Solids and Structures*, **41**: 2043-2064.
[8] A.P.S. Selvadurai and Suvorov, A.P. (2012) Boundary heating of poroelastic and poro-elastoplastic spheres, *Proceedings of the Royal Society, Mathematical and Physical Sciences Series A*, doi: 10.1098/rspa.2012.0035.

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