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MODELLING GEO-ENVIRONMENTAL ENGINEERING PROBLEMS BY MEANS OF POROUS MEDIA MECHANICS

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ABSTRACT

Environmental problems in Geomechanics are essentially multi-physics problems and often involve transport of some substance. Transport of contaminants and other substances may occur in underground fluids, e.g. in water, water vapour and air, filling the pores of porous solid materials. Mass transport also takes place in reservoir engineering problems, where the fluids involved are oil, water and gas. Transport phenomena alone have been well studied but much less so their effects in connection (coupling) with the deformation of the solid matrix. It is the case of surface subsidence due to either groundwater withdrawal or as experienced above exploited hydrocarbon reservoirs, where capillary effects at reservoir level could play a role as far as they may produce either swelling of the formation if the reservoir is in the elastic range or irreversible volumetric compaction if the yield locus is reached, e.g. [1]. Another important area deals with mechanical aspects of waste management. Industrial waste (hazardous and non hazardous), mining, municipal, nuclear, and dredging waste must be safely disposed of. The safe disposal of highly radioactive nuclear waste deserves particular attention. Common materials for such barriers are soil, rock or concrete. The behaviour of these materials in deep and surface disposal conditions has to be studied from the point of view of safety and durability. Another important topic with environmental implications is the onset of landslides due to rainfall and the Thermo-Hydro-Mechanical (THM) analysis of lagoon salt marshes.

This paper presents a general framework for the computational analysis of geo-environmental mechanical problems. It is based on a fully coupled heat and multiphase flow in deforming porous media. The porous medium is assumed to be a multiphase system where interstitial voids of the solid matrix may be filled with water (with dissolved air), water vapour and dry air (gas) [2]. To handle this multiphase system, the general frame of averaging theories is used in deriving the governing equations [3], [4]. The governing equations are derived and then discretised by means of the finite element method for coupled problems in space and time [4], [5].

The numerical examples will show applications of the full set of equations. In choosing the examples, validation of the model will be kept in mind. Coupled heat, water and gas flow in deforming porous media, are validated against existing numerical solutions, e.g. [4]. The constitutive laws are validated against physical experiments [6].

Examples given involve the simulation of the onset of landslides in pyroclastic soils due to rainfall [7] and the groundwater and saturation response of a typical salt marsh of the Venice lagoon (Italy) subjected to both tide fluctuation and flooding [8]. Moreover, if possible, the simulation of a surface subsidence problem due to the production of natural gas and that of the THM behaviour of a nuclear waste disposal in a geological clay formation will be shown.

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