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Thermo-poroelastic response of an argillaceous limestone

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Argillaceous limestones are now being considered by many countries that intend to develop deep geologic storage facilities for siting both high-level and intermediate- to low-level nuclear fuel wastes. In deep geologic settings for high level nuclear wastes, the heating due to radioactive decay is transmitted through an engineered barrier, which consists of the waste container and an engineered geologic barrier, which consists of an encapsulating compacted bentonite. The heat transfer process therefore leads to heating of the rock mass where the temperature of the rock is substantially lower than the surface temperature of the waste container. This permits the use of mathematical theories of poroelastic media where phase transformations, involving conversion of water to a vapour form are absent. While the thermo-poroelastic responses of geologic media such as granite and porous tuff have been investigated in the literature, the investigation of thermo-poroelastic responses of argillaceous limestones is relatively new. Argillaceous limestones are considered to be suitable candidates for siting deep geologic repositories owing to the ability to accommodate stress states with generation of severe defects that can influence their transmissivity characteristics. Also the clay fraction in such rocks can contribute to long term healing type phenomena, which is a considerable advantage. This research presents the results of a laboratory investigation and computational modelling of the same that examines the applicability of the theory of thermo-poroelasticity, which extend Biot's classical theory of poroelasticity to include uncoupled heat conduction. The experimental configuration involves the boundary heating of a cylinder of the Cobourg Limestone from southern Ontario, Canada. The cylinder measuring 150 mm in diameter and 278 mm in length contains an axisymmetric fluid-filled cylindrical cavity measuring 26 mm in diameter and 139 mm in length. Thermo-poroelastic effects are induced by instantaneously raising the boundary temperature of the cylinder from 25oC to either 40oC or 60oC. The thermo-poroelastic effects will lead to the generation of pore fluid pressures in the sealed cavity. The cavity fluid pressures will increase with time and will decay as the excess pressure diffuse into the argillaceous limestone. This pressure pulse signature is used to validate the applicability of a thermo-hydro-mechanical model, where the mechanical, physical and flow parameters used have been determined form separate tests. The correlation between the experimental results and the computational predictions are also assessed in terms of a sensitivity study where ranges of estimates are assigned for parameters with critical influences.

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