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A thermodynamics-based theory for the thermo-poro-mechanical modeling of Saturated Clay

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Abstract: A non-equilibrium thermodynamics-based theory is established in this study for the unified thermo-poro-mechanical (TPM) modeling of saturated clays subjected to monotonic and cyclic mechanical/thermal loads. The multi-physical and multi-phase thermodynamics of saturated clays is developed, based on which the TPM coupled constitutive relations are derived from thermodynamic principles. The thermo-elastic coupling is derived by defining the elastic potential energy of soil as a function of elastic strain and temperature; the thermo-viscoplastic coupling is described according to the energy dissipations, in which the phase change of bound pore water induced by heating-cooling cycles is considered as a fundamental mechanism of the irreversible thermal deformation of clays. The theory is validated by predicting the triaxial compression tests, the pure principle stress rotation tests and the monotonic/cyclic heating-cooling tests of clays. The effects of stress state, stress history and drainage condition on the cyclic TPM coupled behavior of saturated clays are studied using the model. The developments of thermal strain and excessive pore pressure induced by pure thermal loads are well predicted and depend on the over-consolidation state and the drainage conditions. The normally or slightly over-consolidated clays show remarkable accumulations of thermal volume contraction after several cycles of temperature. As a result, the effects of temperature on the drained/undrained shear stiffness and strength of soils subjected to monotonic and cyclic loads can also be well interpreted.

KEYWORDS: A. Thermomechanical processes; B. Constitutive behaviour; C. Energy methods; Clay

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