Contribution ID: **85** Type: **Oral Presentation**

Adsorption induced Effective Stress in Porous Media

Thursday, 16 May 2024 09:20 (15 minutes)

Adsorption and capillarity, in the order of high free energy to low, are the two soil–water interaction mechanisms controlling the hydro-mechanical behaviour of soils. Yet most of the poroelasticity theories of soil are based on capillarity only, leading to misrepresentations of hydro-mechanical behaviour in the low free energy regime beyond vaporisation. This inability is reasoned to be caused by two major limitations in the existing theories: missing interparticle attraction energy and incomplete definition of adsorption- induced pore-water pressure. A poroelasticity theory is formulated to incorporate the two soil–water interaction mechanisms, and the transition between them –that is, condensation/vaporisation, by expanding the classical three-phase mixture system to a four-phase mixture system with adsorptive water as an additional phase. An interparticle attractive stress is identified as one of the key sources for deformation and strength of soils induced by adsorption and is implemented in the poroelasticity theory. A recent breakthrough concept of soil sorptive potential is utilised to establish the physical link between adsorption-induced pore-water pressure and matric suction. The proposed poroelasticity theory can be reduced to several previous theories when interparticle attractive stress is ignored. The new theory is used to derive the effective stress equation for variably saturated soil by identifying energy-conjugated pairs. The derived effective stress equation leads to Zhang and Lu's unified effective stress equation, and can be reduced to Bishop's effective stress equation when only the capillary mechanism is considered and to Terzaghi's effective stress equation when a saturated condition is imposed. The derived effective stress equation is experimentally validated for avariety ofsoil in the full matric suction range, substantiating the validity and accuracy of the poroelasticity theory for soil under variably saturated conditions.

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References

Conference Proceedings

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Session Classification: MS12

Track Classification: (MS12) Advances in computational and experimental poromechanics