Modelling approaches for desiccation cracking in clay soils - COMPLAS 2017

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ABSTRACT

Soil desiccation and associated cracking involves highly non-linear processes of moisture and vapour flow leading soil consistency changes, shrinkage and fracture. Cracking is soil's response to minimising the free energy of soil/water system during desiccation subject to restraints against potential shrinkage in the soil matrix. Due to complex interaction of these processes, a multitude of resulting behaviours is possible, which has sometimes led to difficulties in understanding and modelling of this phenomenon. In the present paper, we present key underlying mechanisms and how they may be modelled mathematically.

If soil dries without any restraints, free shrinkage (ε_{sh}) would normally ensue isotopically without any cracking, as a function of the conditions of the drying environment. If any restraints are provided (either internal or external), soil can crack during desiccation. Experiments we have undertaken using distributed fibre optic sensors indicate that soil is in compression or has observed shrinkage strains (ε_{kl}) when the cracking occurs. This means from an effective stress point of view, it experiences positive (compressive) effective stresses at the point of cracking. However, restraints induce negative or tensile total stresses (σ_{ij}) and cracking may be considered to occur when stresses reach the tensile strength of the soil defined using total stresses. This mechanism is normally represented in moisture-decoupled incremental from by the equation: $d\sigma_{ij} = D_{ijkl} d\varepsilon_{kl} - 3Kd\varepsilon^{sh}\delta_{kl}$, where, D_{ijkl} is the tangent stiffness matrix, $d\varepsilon_{kl}$ is the observed strain increment and K is the tangent bulk modulus [1], [2]. This requires that failure is initiated by failure in fluid menisci that leads to loss of suction or local air entry. We review various modelling approaches used by researchers.

The fracture propagation, however, is influenced by the fracture energy of the soil (Mode I), which is approximately equal to surface tension of water in slurry state but increases dramatically as the soil moisture content decreases. With experimental evidence, we present the total fracture energy is comprised of three components: water G_w, soil particle surface, G_{sp} and soil shear G_{ss} giving $G_s = G_w + G_{sp} + G_{ss}$. For numerical modelling, the fracture processes is presented as a cohesive fracture with a fracture process zone. Fracture energy would evolve as soil consistency changes. In a general case, fractures could develop not only in Mode I but in shear (Mode II) or in mixed mode. To allow for this, a parabolic failure model defined in $\tau - \sigma$ space is used, which evolves as the de-cohesion progresses. Some applications of the model to laboratory and field desiccation problems are presented.

REFERENCES

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