A model for multiphase flow and transport in porous media including a phenomenological approach to account for deformation—a model concept and its validation within a code intercomparison study

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Abstract Multiphase flow processes in unsaturated cohesive soils are often affected by deformation due to swelling and shrinking as a result of varying water contents. This paper presents a model concept which is denoted ‘phenomenological’ in terms of the processes responsible for soil deformation, since the effects of deformation on flow and transport are only considered by constitutive relations that allow an adaptation of the hydraulic properties. This new model is validated in a detailed intercomparison study with two state-of-the-art models that are capable of explicitly describing the processes relevant for the deformation. A ‘numerical experiment’ with a state-of-the-art reference model is used to produce ‘measurement data’ for an inverse-modelling-based estimation of the model input parameters for the phenomenological concept.

Keywords Numerical modelling · Multiphase · Multicomponent · Cohesive clays · Soils · Deformation · Swelling and shrinking

Abbreviations

A Abaqus model
M MUFTE model
f Model accounts for flow and transport only
d Model accounts for flow and transport, as well as deformation due to gravity and capillarity
s Model additionally accounts for swelling

Nomenclature

\begin{align*}
\alpha_{VG} & \quad (\text{Pa}^{-1}) \\
\epsilon & \quad (–) \\
\epsilon_v & \quad (–) \\
\epsilon' & \quad (–) \\
\epsilon_{process} & \quad (–) \\
\epsilon_{L/T/U} & \quad (–) \\
\vartheta & \quad (–) \\
\vartheta_e & \quad (–) \\
\vartheta_r & \quad (–) \\
\vartheta_s & \quad (–) \\
\mu_\alpha & \quad (\text{Pa s}) \\
\nu & \quad (–) \\
\varrho_\alpha & \quad (\text{kg m}^{-3}) \\
\varrho_{mol, tot} & \quad (\text{mol m}^{-3}) \\
\varrho_{mol, \alpha} & \quad (\text{mol m}^{-3}) \\
\end{align*}

van Genuchten parameter
Strain tensor
Volumetric strain
Swelling and shrinking factor
Change of the swelling and shrinking factor due to a certain process
Swelling and shrinking factor at lower, transition and upper data points (cf. Fig. 3)
Volumetric water content
Effective volumetric water content
Residual volumetric water content
Volumetric water content at water saturation
Dynamic viscosity of phase \( \alpha \)
Poisson’s ratio
(Mass) density of phase \( \alpha \)
Total molar density of water
Molar density of phase \( \alpha \)