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PROCEEDINGS

Nonlinear Constitutive Modeling of Porous/Non-Porous Media at Different Scales

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ABSTRACT

Building materials such as concrete cement or concrete asphalt are highly heterogeneous composite materials that are often addressed as homogeneous media when a sufficiently large Representative Elementary Volume (REV) definition of the compound is accepted. Adopting a homogenous approach in the material behaviour modeling typically fails to elucidate the interaction between the various material phases. Recently, a meso-scale approach has emerged, enabling the study of composite/conglomerate materials within the REV volume, thereby making the principal material components explicit. At this scale, local interactions between inclusions and matrix are captured, revealing the presence of complex triaxial stress states within the material under loading.

Concrete materials can be conceptualized at the meso-scale as three-phase heterogeneous media comprising coarse aggregates, matrix, and the Interfacial Transition Zone (ITZ) between the matrix and inclusions. Meso-scale modeling necessitates accurate geometry reconstruction and adequately sophisticated material description. Generally, geometry can be acquired through industrial tomography or by means of specific random distribution algorithms capable of reproducing the correct grading curve. A visco-elasto-plasto-damage model is proposed to assess concrete materials under varying loading conditions, with different approaches to geometry reconstruction being applied.

External sulphate attack is one of the relevant degradation processes that may compromise the durability of concrete structures, especially geotechnical ones located in soils rich in sulphate ions and with high moisture content. A chemical-mechanical coupled numerical model for meso-level analysis of the degradation process is adopted, considering the use of zero-thickness interface elements to represent fracture. A staggered strategy, between the mechanical problem and the diffusion-reaction problem, that corresponds to the ingress of sulphate ions, is performed. 3D numerical studies that can reproduce the expected "onion-shaped" cracking mode are developed.

Predicting the waves propagation within porous media is still a challenging task for engineers and researchers from different fields. An example could be the simulation of the seismic wave in a soil medium in order to deduce the destructive forces acting on buildings. For this reason, a fully coupled multi-field model for the dynamic simulation of anisotropic porous materials is referred. Furthermore, The Bi-Conjugate Gradient Stabilized (Bi-CGStab) algorithm has been accelerated by a suitable preconditioning technique. Finally, dynamic analyses are performed, in order to test the computational efficiency of the developed numerical tool and to investigate the behavior of seismic waves in a fully saturated anisotropic soil.

When accounting for cyclic mobility problems, repeated loading conditions might affect the computational cost. Therefore, the efficiency of finite elements represents a crucial aspect of speeding up the design process. Additive hypoelastic-based and multiplicative hyperelastic-based constitutive equations of the Extended Subloading Surface model for three-dimensional finite elements adopting fully implicit integration schemes are considered. Particularly, the constitutive equations of the Extended Subloading Surface theory are reformulated for shell and plane stress elements, aiming to obtain an efficient computational tool suitable for cyclic mobility problems. The numerical implementation considers isotropic hardening, kinematic hardening, and material anisotropy.

KEYWORDS

Constitutive modeling; meso-scale approach; visco-elasto-plasto-damage analysis; fracture; sulphates; bi-conjugate gradient stabilized algorithm; extended subloading surface model

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