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MODELING OF FREEZING AND THAWING CYCLES OF SATURATED POROUS MEDIA

Joachim Bluhm[1], Tim Ricken[2] and [1] * Moritz Bloßfeld[3]

[1] Faculty of Engineering, Department of Civil Engineering, Institute of Mechanics, University Duisburg-Essen, 45117 Essen, Germany
joachim.bluhm@uni-due.de

[2] Faculty of Engineering, Department of Civil Engineering, Institute of Mechanics, University Duisburg-Essen, 45117 Essen, Germany
tim.ricken@uni-due.de

[3] Faculty of Engineering, Department of Civil Engineering, Institute of Mechanics, University Duisburg-Essen, 45117 Essen, Germany
moritz.blossfeld@uni-due.de

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ABSTRACT

In civil engineering, the freezing and thawing processes of porous media with regard to the frost durability of solid materials compose a worthwhile topic for investigation. Each construction or body which is in contact with liquid and frozen water is defined in terms of its resistance to the environment, e.g. frost damage to porous building materials like road pavements and concrete in regions with periodic or permanent freezing are well-known. At the same time, artificial freezing techniques for tunneling in non-cohesive soils and other underground constructions for protection of excavation and for compartmentalization of contaminated tracts will be used.

Freezing and thawing cycles within saturated porous media are definitively characterized by thermo-mechanically coupled phenomena of individual constituents and the thermo-mechanical interactions between the phases of porous media. In freezing porous media, ice formation is a phenomenon of coupled heat and mass transport and caused primarily by the expansion of ice. The volume increases due to the freezing front inside the porous solid.

Within the framework of the Theory of Porous Media (TPM), a model for the description of the freezing and thawing processes in saturated porous materials will be discussed, where a porous medium consisting of four phases is taken into consideration: solid, ice, liquid and gas. Solid, ice and liquid are considered incompressible, i.e. the changes of the partial densities of the incompressible phases are proportional to the corresponding volume fractions. For the purpose of simplification only the influence of gas in terms of the compensation of the volume expansion of water during freezing processes is taken into account. Furthermore, transport phenomena with and without phase transition are encountered during freezing and thawing.

In reality, as well as in standard experiments and with respect to saturated porous media, it can be observed that the fluid flow is slow. Therefore, dynamic effects are neglected in the model. Furthermore, it is postulated that the local temperatures of all constituents are equal and the motions of solid and ice

are the same. Regarding the mass supply terms it is assumed that mass exchange is restricted to ice and liquid, see BLUHM & RICKEN [1].

The main focus of the macroscopic model is on the constitutive relations, the dissipation mechanism and the thermodynamic state variables (energy, entropy and enthalpy). Regarding the ansatz of the entropy for the individual phases, the entropy of the total system has to grow, but the entropy of the individual phases develop differently.

The field equations in the TPM are the balance equations for the individual constituents, the saturation condition and the restrictions for the corresponding supply terms of mass, momentum and energy. Readers interested in the foundation of the governing equations are referred to DE BOER [2]. With respect to the numerical simulations of freezing and thawing processes in saturated porous media the weak forms of the field equations will be presented, considering the afore-mentioned simplifications. In order to solve the boundary and value problems the finite element method is used. For time discretisation the Newmark method is introduced. For further information concerning the numerical treatment readers are referred to RICKEN *et al.* [3].

In any case, the numerical simulation for the application of the macroscopic model in practice, in terms of freezing and thawing hysteresis, will be under examination. Additionally, the local and temporal changing of thermodynamic state variables will be presented in examples.

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