III European Conference on Computational Mechanics
Solids, Structures and Coupled Problems in Engineering
C.A. Mota Soares et al. (eds.)
Lisbon, Portugal, 5–8 June 2006

Concrete at Early Ages and Beyond: Numerical Model and Validation

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ABSTRACT

This work deals with a new mathematical/numerical model for the analysis of the behaviour of concrete considered as multiphase viscous porous material from early ages to long term periods.
This is a solidification-type model where all changes of material properties are expressed as functions of hydration degree, and not maturity nor equivalent hydration period as in maturity-type models. A mechanistic approach has been used to obtain the governing equations, starting from micro-scale, by means of modified averaging theory, also called hybrid mixture theory, [1-2]. Constitutive laws are directly introduced at macroscopic level. An evolution equation for the internal variable, hydration degree, describes hydration rate as a function of chemical affinity, considering additionally to the existing models, an effect of the relative humidity on the process. The model takes into account full coupling between hygral, thermal and chemical phenomena, as well as changes of concrete properties caused by hydration process, i.e. porosity, density, permeability, and strength properties. Phase changes and chemical phenomena, as well as the related heat and mass sources are considered. Some examples showing possibilities of the model for analysis of autogenous self-heating and self-desiccation phenomena, as well as autogenous shrinkage are presented and discussed. Creep processes are modelled considering concrete as viscous-elastic material with aging caused by solidification of non-aging constituent, i.e. solidification theory for the so-called basic creep [1-2]. A Kelvin-type chain has been chosen for the definition of the compliance function, which corresponds to an expansion of that function in a Dirichlet's series. Shrinkage is defined using the effective stress principle, as usual in the mechanics of porous materials, and it is coupled to the creep model. In such a way it is possible to have creep strains even if the concrete structure is not externally loaded. Capillary shrinkage is, in fact, characterized from capillary tensions which can be seen as a sort of internal load for the microstructure of the material. A series of numerical computations compared to the experimental results are presented as validation of the model described above.

References

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