

# FE MODELING OF HYDRO-THERMO-CHEMO-MECHANICAL BEHAVIOR OF CONCRETE AT EARLY AGES

**B.A. Schrefler<sup>a</sup>, F. Pesavento<sup>a</sup> and D. Gawin<sup>b</sup>**

<sup>a</sup>Department of Structural and Transportation Engineering  
The University of Padua  
Via Marzolo 9, 35131 Padova, Italy  
bas@caronte.dic.unipd.it, pesa@caronte.dic.unipd.it

<sup>b</sup>Department of Building Physics and Building Materials  
2256 Seamans Center  
The Technical University of Łódź  
Al. Politechniki 6, 93-590 Łódź, Poland  
gawindar@ck-sg.p.lodz.pl

Prediction of behavior of concrete structures at early ages, particularly the massive ones, is of great practical importance. During the initial period of concrete maturing complex physico-chemical phenomena cause considerable non-uniform deformations of concrete due to self-heating, autogenous self-desiccation and drying processes. Most models of concrete at early ages consider only thermo-mechanical phenomena, assuming that in fresh concrete hydral phenomena are of less importance because the material is fully or almost fully saturated with liquid water. This is not always the case, especially for HPC and UHPC where autogenous self-desiccation causes considerable decrease of relative humidity and resulting shrinkage appears even after a couple of days of concrete curing. Then, concrete structures can be exposed to drying from initial stages of their casting. Hence there is a need for models accounting also for hygral phenomena.

A mechanistic approach has been used in [1] to obtain the governing equations for maturing concrete. The developments start at the micro-scale and balance equations for phases and interfaces are introduced at this level and then volume averaged to obtain macroscopic balance equations. Constitutive laws are directly introduced at macroscopic level. The final equations: mass (water species and dry air), energy and momentum conservation equations have been written in terms of the chosen state variables: temperature, gas pressure, capillary pressure, displacement vector, and chemical affinity. The model takes into account coupling between hygral and thermal and chemical (cement hydration) phenomena, as well as changes of concrete properties caused by the latter process. The changes of porosity, density, permeability, and strength properties during maturing of concrete are expressed as functions of the hydration degree. The evolution of the cement hydration, associated with exothermic chemical reactions, is described by means of the thermodynamic, macroscopic theory by Coussy and Ulm, [2]. Phase changes and their heat effects are considered. Creep processes are modeled considering concrete as visco-elastic material with aging caused by solidification of non-aging constituents, [3]. Aging process is described in terms of the hydration degree, what is a change in comparison to the classical theory by Bazant and Prasannan, [3]. The model equations are discretised in space by use of FEM, and temporal discretization is done by means of a fully implicit scheme of FDM. The computer research code HMTRA, [1], has been appropriately modified and applied for analysis of some 1-D and 2-D maturing concrete elements.

## References

- [1] D. Gawin, "Modelling of hygro-thermal behaviour of fresh concrete", in W. Baranski, and C. Boutin (eds.), *Homogenization Methods in Civil Engineering*, Editions of Technical University of Łódź, p. 179-196, 2002.
- [2] F.-J. Ulm, and O. Coussy, "Modeling of thermo-chemo-mechanical couplings of concrete at early ages", *Journal of Engineering Mechanics*, ASCE, v. 121(7), p. 785-794, 1995.
- [3] Z.P. Bazant, and S. Prasannan, "Solidification theory for concrete creep. I: Formulation, II. Verification and application", *Journal of Engineering Mechanics - ASCE*, v. 115, p. 1691-1725, 1989.