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EFFECTIVE STRESS PRINCIPLE IN MODELLING SHRINKAGE AND CREEP OF CONCRETE AT EARLY AGES AND BEYOND

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ABSTRACT

In this work a novel numerical model of hygro-thermal and hydration phenomena in concrete at early ages and beyond is presented. This is a solidification-type model where all changes of material properties are expressed as functions of the hydration degree, and not the maturity nor equivalent hydration period as in the maturity-type models. A mechanistic approach, typical in the mechanics of porous media, was used to obtain the governing equations, by means of a hybrid mixture theory. The final equations, mass (water species and dry air), energy and momentum balances are written in terms of the chosen primary variables: gas pressure, capillary pressure, temperature and displacements. The model [1-3] 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. Phase changes and chemical phenomena, as well as the related heat and mass sources are considered. For a more detailed description of the mathematical model, the governing equations and the constitutive relationships, see [1-3].

Kinetics of cement hydration is described by means of an evolution equation which relates the internal variable, hydration degree, with the hydration rate through the chemical affinity. The latter one is considered as the driving force of the chemical reaction, [1-3].

For concrete deformations, the effective stress concept, widely employed in mechanics of porous media, has been used. A new form of relationship defining the effective stresses in concrete has been deduced from general thermodynamic considerations [1-3], and its' parameters have been determined using the published experimental data for two types of concrete and cement pastes, [1-3]. In the proposed model both shrinkage and creep strains are directly dependent on the effective stress.

The pressure exerted by the pore fluids on the solid skeleton causes its volumetric deformation (shrinkage strain), hence we expect that it will contribute to the creep strains as well. Indeed, some experimental studies of autogenous deformations of concrete at early ages suggest that a part of the material strains in such a situation (i.e. without any external load) can be explained only by the creep deformations due to the

capillary forces.

The solidification theory [4] is used for the description of the so called basic creep. Therefore creep processes are modelled considering concrete as visco-elastic material with aging caused by solidification of non-aging constituents [4]. In particular the continuous retardation spectrum technique has been applied in the evaluation of the spring modulus. For the description of the long-term creep and the stress induced creep (part of the so called drying creep) the microprestress concept, originally proposed in [5], has been modified for taking into account the porous nature of concrete considered in our approach.

A method of two-scale modelling of concrete, based on the so-called numerical homogenization approach has been recently developed. The macroscopic, effective properties of the material are obtained by means of up-scaling of the results from the meso-scale. At the meso-level, the representative elementary volume (REV) of the material is modelled as a composite, made of the inclusions of water reservoirs and the surrounding maturing concrete. The simulations focus on up-scaling of the transport mechanisms of water from internal water-reservoirs into concrete and determination of the effective properties for macro-scale simulations. The detailed analysis of fluxes of thermodynamic quantities in REV is carried out in order to obtain the transport properties of the medium at the macro-level.

This model is applied for the analysis of hygro-thermal phenomena and deformation of cement based materials exposed to internal curing. Numerical simulations carried out, focus on the influence of pre-saturated water reservoirs dispersed in concrete (light weight aggregates or super absorbent polymers), upon the effective properties of the material and its performance during maturing and exploitation in different environmental conditions. Presented results of the numerical simulations are verified against some published experimental data.

REFERENCES

[1] D. Gawin, F. Pesavento, B.A. Schrefler, "Hygro-thermo-chemo-mechanical modelling of concrete at early ages and beyond. Part I: Hydration and hygro-thermal phenomena", *Int. J. Num. Meth. Engng*, Vol. **67**, pp. 299-331, (2006).

[2] D. Gawin, F. Pesavento, B.A Schrefler, "Hygro-thermo-chemo-mechanical modelling of concrete at early ages and beyond. Part II: Shrinkage and creep of concrete", *Int. J. Num. Meth. Engng*, Vol. **67**, pp. 332-363, (2006).

[3] D. Gawin, F. Pesavento, B.A. Schrefler, "Modelling creep and shrinkage of concrete by means of effective stress", DOI: 10.1617/s11527-006-9165-1, *Materials & Structures*, Vol. **40**, pp. 579-591, (2007).

[4] Z.P. Bazant, "Mathematical Modeling of Creep and Shrinkage of Concrete", John Wiley & Sons, Chichester, 1988.

[5] Z.P. Bazant, A.B. Hauggaard, S. Baweja, F-J. Ulm, "Microprestress-solidification theory for concrete creep. I: Aging and drying effects", *Journal of Engineering Mechanics ASCE*, Vol. **123**(11), pp. 1188-1194, (1997).