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A MULTISCALE/MULTIPHYSICS MODEL FOR CONCRETE

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ABSTRACT

In this paper a general model for the analysis of concrete as multiphase porous material, based on the so called Hybrid Mixture Theory, is presented. The development of the model equations, taking into account both bulk phases and interfaces of the multiphase system is described, starting from the microscopic scale. An exploration of the second law of thermodynamics is also presented: it allows to define several quantities used in the model, like capillary pressure, disjoining pressure or effective stress, and to obtain some thermodynamic restrictions imposed on the evolution equations describing the material deterioration. Three specific forms of the general model adapted to some significant engineering applications are presented and discussed:

1) *concrete structures under fire*: the general model can be applied to the analysis of behaviour of concrete structures under high temperature and pressure. In these conditions concrete structures experience spalling phenomenon, which results in rapid loss of the surface layers of the concrete at temperature exceeding about 200-300°C, see [1].

2) *concrete at early ages and beyond*: in this case the general model has been enhanced by incorporating a specific model for assessing the hydration/aging of the material and the short/long term creep. This is 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. 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, [2].

3) *concrete structures subject to leaching process*: calcium leaching is of importance during assessment of durability of concrete structures exposed to direct contact with deionised water. Usually thermodynamic equilibrium of the calcium ions in pore solution and the solid calcium in material skeleton, as well as purely diffusive calcium transport, are assumed in modelling of the process. This is modelled here by considering thermodynamic imbalance of the calcium in solid and liquid phases. Moreover, the leaching model is non isothermal. It allows for analyses of durability of concrete structure in various conditions, also those which were before impossible to model, such as for example leaching due to existing water pressure gradient and/or with thermal gradients [3]. Some numerical simulations aimed to prove the validity of the approach adopted also are presented and discussed.

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Since several years, a new trend characterises some architectural realizations following the so-called “Bilbao effect”. “Blob”, “liquid”, “flexible” are as many qualifiers that are used to describe them. Their common character relies in very complex forms often composed of double curved surfaces (“free form design”).

It is a matter of fact that this freedom for forms during the conceptual design phase, ends in very complex situations for engineers and builders. Freedom for some designers may also put their partners in “jails of nightmares”. We try to show that in classical situations, many parameters are coupled, and mainly those associated to form and structural composition.

It is consequently necessary to understand the morphogenesis of building systems. History of architecture is marked out by archetypal forms according to different constraints: pure geometric ones, mechanically constraints governing formfinding process.

It is then useful to imagine weaving again new links between parameters which condition the form, and the other parameters of the free form design. Among others, we just introduce Pascalian forms, whose generation mode can be used all through the design process.