Homogenization in coupled heat and moisture transport and its efficent implementation on parallel computers

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Coupled heat and moisture transfer is studied in many problems of civil engineering practice. Distribution of temperature and relative humidity or volumetric moisture content has influence on mechanical behaviour of materials. The opposite coupling, i.e. the influence of mechanical characteristics on transport processes is usually neglected.

This contribution is based on the Künzel model introduced in reference [1]. The model is based on two unknown variables, temperature and relative humidity, which are used in the balance equation for the heat and for the moisture content. The two governing equations are nonlinear partial differential equations which lead after space and time discretization to a sequence of nonlinear systems of algebraic equations solved by the Newton-Raphson method combined with LU factorization.

A strong material heterogeneity together with a significant dependence of the model parameters on initial conditions as well as the gradients of heat and moisture fields justifies the use of a hierarchical modeling strategy to solve the problem of this kind. Attention is limited to the classical first order homogenization in a spatial domain developed here in the framework of a two step (meso-macro) multi-scale computational scheme.

Representative volume elements being identical, at least in a statistical sense, to a real meso-structure from both the geometrical and material composition point of view are generated. The whole structure is modelled on the macro-scale level where the finite elements are not generated with respect to the particular materials. Appropriate representative volume element is assigned to each integration point of a macro-scale level finite element. It means, a meso-scale level problem is solved for each integration point of the macro-scale level. Processor farming is used in order to speed up the computation. The macro-scale level problem is assigned to the master processor while the meso-scale level problems are spread over the slave processors.

The multi-scale approach was used in the analysis of coupled heat and moisture transfer in the historical Charles Bridge in Prague. A two-dimensional cross-section of Charles Bridge subjected to actual climatic conditions is analyzed next to confirm the suitability of algorithmic format of the multi-scale scheme for the parallel computing.

References

[1] H.M. Künzel, "Simultaneous Heat and Moisture Transport in Building Components", Fraunhofer Institute of Building Physics, Fraunhofer IRB Verlag Stuttgart, 1995.