A multifield discrete model for concrete

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ABSTRACT

Concrete is one of the most commonly used building materials in the world. Due to the widespread application there are also many external and internal influences determining the lifetime of a structure. Modelling the mechanical, physical and chemical processes is therefore important to predict the behaviour of the material.

In this approach the discrete element method is used to describe the heterogenous structure of concrete. Based on the model from Cundall[1], a three-dimensional bonded contact model is evolved. The aim is to model processes taking place in the microstructure of concrete. Therefore the different phases are modelled by different kind of particles. It should be noticed that the described model is placed beside the common used theory of porous media.

A given domain is discretized with rigid spherical particles where the mechanical field is realized with spring-damper systems between two particles. The spring stiffness, as an micromechanical parameter, can be adapted to fulfill the global Youngs's modulus and Poisson's ratio. According to that the temperature field is developed. Instead of the spring stiffness the thermal resistance between two particles is used and a three-dimensional thermal pipe network[2] is evolved where the heat flux occur. With the known temperature at each particle the thermo-mechanical coupling condition is evaluated. The velocity of contraction or expansion leads to contact forces so that the position of the particles can be updated.

During lifetime there a many chemical reactions taking place inside the structure. While the hydration reactions in the first hours and days are very important for the strength and durability there are also different reactions which can destroy the structure of concrete. To deal especially with latter the chemical field is applied to the model with the goal to consider an arbitrary reaction on a particle. To obtain the change of mass in a timestep the reaction equation is normed by the molar mass of the governing substrate. The amount of mass is then computed by taking the reaction rate into account which can be determined by experiments.

The linkage between the thermal and the chemical field is applied to the model. Because the reaction rate is naturally temperature dependent, the influence from the thermal field on the chemical field is implicitly included. An arbitrary reaction can be exotherm or endotherm that means heat producing or consuming. This effect is considered by the reaction enthalpy. Due to that the heat energy can be directly applied to the particle. This way a thermo-chemical coupled model is created.

REFERENCES

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[2] Y.T. Feng, K. Han, D.R.J. Owen. *Discrete Thermal element modelling of heat conduction in particle systems: Pipe-network model and transient analysis.* Powder Technology 193(3), 248-256, 2009