

A multifield discrete element model for concrete

Christian Flack*, Felix Ockelmann[†] and Dieter Dinkler[†]

^{*†} Technische Universität Braunschweig
Institute of Structural Analysis
Beethovenstr. 51, 38106 Braunschweig
e-mail: c.flack@tu-braunschweig.de

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 order to describe the heterogeneous structure of concrete the discrete element method is used. Based on the model from CUNDALL [1] for granular assemblies, 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. Further 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 Young'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 occurs. 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.

Considering the whole lifetime of a structure there are many chemical reactions taking place inside. In an early stage the hydration reactions are very important for strength and durability. Later there are also different chemical reactions which can destroy the structure of concrete. To deal especially with latter the chemical field is applied to the model with the objective to consider an arbitrary reaction on a particle. If the reaction equation is normed by the governing substrate, the change of mass in a single time step can be obtained. In order to get the amount of mass, the reaction rate is taking 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 exothermic or endothermic 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).