Discrete element simulation of concrete fracture using polygonal elements

Birgit Beckmann*and Manfred Curbach*

[*] Institute of Concrete Structures, TU Dresden
August-Bebel-Straße 30/30A, 01219 Dresden, Germany
e-mail: Birgit.Beckmann@tu-dresden.de, web page: http://www.massivbau.tu-dresden.de

ABSTRACT

Concrete fracture phenomena and their statistically varying character are investigated in this work. Using a discrete approach for the numerical model, discontinuities are an inherent property of the simulation method. Due to this property, discrete approaches are favourable for the simulation of cracks and the investigation of failure processes. It is the complex processes of failure mechanisms, crack propagation and damage evolution which are specifically investigated rather than to reach a certain maximum load or to investigate the concrete behaviour within a range of safe working loads. In order to go into this matter, a two-dimensional numerical simulation based on the Discrete Element Method (DEM) is used for the analysis of concrete behaviour under compression load. Regarding the particle shape, polygonal particles are chosen. One of the reasons for this choice is the generation of a dense particle ensemble. Due to the polygonal particle shape, the simulation is limited to only two dimensions up to now, although the simulation is principally designed with three dimensions, of course. With regard to the calculation of the interaction forces of contacting particles, a convex shape of the particles is necessary. In order to consider both convex and concave specimen geometries, particles on a concave corner are divided into subparticles during particle generation. This is to preserve the convex shape of the particles themselves even in the case of concave geometries of the whole test specimen. Regarding the particle generation, the generation of a substructure is shown. The aim is to represent the different concrete components such as aggregate and hydrated cement. Therefore, the two simulations types–one simulation using polygonal particles and one simulation using spherical particles–are combined. At first, a mixture of grains of different diameters is simulated using the simulation with spherical particles. Then, a modified Voronoi-tesselation is done upon the result of the first simulation, i. e.. with the midpoints of the particles representing the aggregate. For the modification, helping points are places around the aggregate particles in randomly varying distances in order to get much smaller and also randomly or statistically varying particles which represent the hydrated cement. Figure 1 shows that this leads to particles of different sizes that are polygonally bounded though they originate from spherical particles. The polygonal shape is required to get a dense particle ensemble. Furthermore the convexity is required for the force calculation. Crack patterns, crack initiation and damage evolution are analysed. The cracks are discrete just as in real laboratory experiments. The cracks arise due to the interaction of the concrete particle elements and without the predefinition of any crack zones or crack elements. The simulation results are compared to the ones of laboratory experiments.

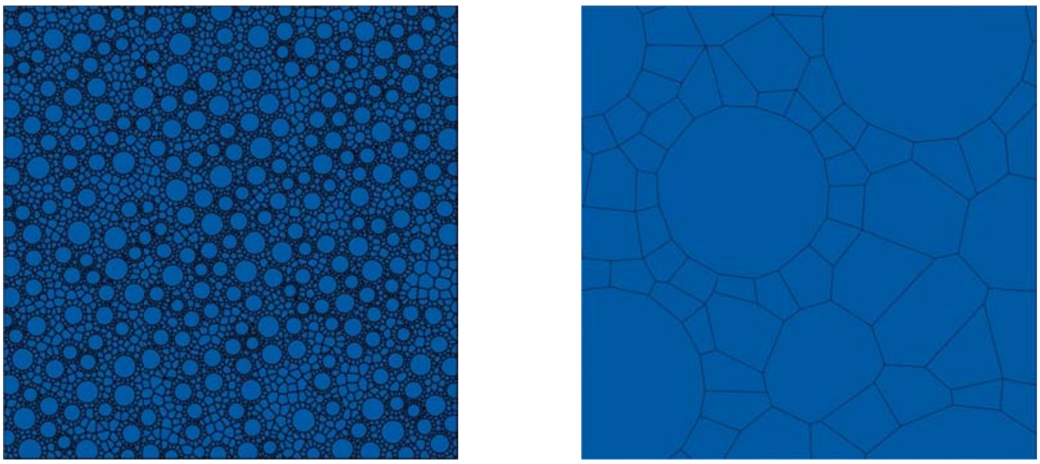

Figure 1: Substructure for aggregate and hydrated cement–ensemble of polygonal particles of different sizes (left overview, right detail)