Modelling the fracture process of fiber reinforced ultra high performance concrete using a three-dimensional discrete element model

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ABSTRACT

Concrete is one of the most commonly used materials in civil engineering. It is highly heterogeneous and does have a very brittle fracture behaviour. Ultra high performance concrete (UHPC) is even more brittle than standard concrete and therefore often used with high caution and safety factors respectively. To get a more ductile failure behaviour it is possible to add fibers to the concrete matrix. Due to its high density and strength, the fibers in UHPC are firmly integrated in the matrix and hardly pulled out by tensile forces. It is therefore very suited to use fibers as reinforcements in UHPC technology.

The Discrete Element Method (DEM) is a widespread method in the field of modeling granular or heterogeneous materials. It is able to capture discontinuities in materials and structures respectively. Based on the model of Cundall [1] for granular assemblies a model for solids is derived and extended to three dimensions. Bonded contacts between two particles are formed with a spring-dashpot-system in three directions at the contact point.

In order to model elasticity, the microscopic DEM model must be able to represent the macroscopic properties of the body. An energy-based method to determine the model parameters proposed by [2] and others can be transferred to the presented three dimensional model. The stored strain energy of all contacts in a given unit cell is added up and divided by the volume of the unit cell to determine a specific energy density. This expression then is derived with respect to the macroscopic strains, which yields stress-strain relations that can be compared to the constitutive equations of the elastic continuum.

Brittle materials are probable to crack. Therefor the advantage of the discrete modelling is used to formulate a failure criterion for the bonded contacts. The local crack initiation is most likely the distance exceedance of two material points. To capture this phenomenon a local strain failure criterion is implemented. After the failure of a contact, a fiber reinforcement is added to the model. Tensile springs are activated if a crack appears to achieve ductile failure behaviour.

REFERENCES

[1] P. A. Cundall, O. D. Strack. A discrete numerical model for granular assemblies. Geotechnique 29 (1), 47-65, 1979.

[2] D. Griffiths, G. G. Mustoe. Modelling of elastic continua using a grillage of structural elements based on discrete element concepts. International Journal for Numerical Methods in Engineering 50 (7), 1759-1775, 2001.