Virtual Concrete Specimens: Discrete Element Simulations of the Quasistatic and Dynamic Material Behavior and Failure Mechanisms of Concrete and Mortar

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ABSTRACT

A Discrete Element approach to the numerical simulation of multiaxial, quasistatic and dynamic material behavior and failure mechanisms of cohesive frictional materials such as concrete or mortar is described. Choosing a Soft Contact approach, a quite minimalistic constitutive law for particle interaction is used to model repulsion, cohesion, viscous damping and static friction. Well-known techniques such as the Linked Cells strategy for runtime optimization are used to handle the computational effort.

The virtual specimens used in the simulations are generated as dense packings of spherical aggregates with particle size distributions that are oriented towards realistic sieving lines for concrete. Typically, the specimens are of cubic, cylindrical, or prismatic shape while other geometries are possible as well.

Real experiments about the damage behavior of concrete provide insight into the damage behavior of the specimens used and – after having carried out a sufficient number of experiments – into the damage behavior of the material itself. However, such experiments always imply destruction and non-reusability. The generation of representative, standardized specimens is a non-trivial task and the application of similar loading scenarios in the testing machine requires considerable skill and care.

Virtual specimens are destructible and indestructible at the same time. Each individual specimen may be used for numerous situations of loading, may they be uniaxial or multiaxial, monotonic or cyclic, possibly for situations that cannot be realized in the laboratory for reasons of principle or for practical reasons. Slight modifications of the size distribution of the virtual aggregates and even the generation of different virtual specimens consisting of an identical ensemble of aggregates (so-called „clones”) are possible and allow to repeat the numerical experiments under slightly different initial conditions any number of times.

By the described approach a good number of characteristic phenomena of material behavior and failure mechanisms of concrete such as crack propagation, relaxation, or spall fracture can be simulated in an at least qualitative manner. As is typical for particle simulations, the field of application of the described model is not at all restricted to the simulation of the material and damage behavior of concrete. As a short outlook a number of further applications are given, which are as different as Dense Sphere Packing, Cluster Finding, or the simulation of Collapsing Dominoes.