# Virtual Concrete Specimens: A Discrete Element Approach to the Generation of Densely Packed Ensembles of Virtual Aggregates

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## ABSTRACT

A Discrete Element approach to the generation of ensembles of densely packed virtual aggregates is described, which can be used for numerical investigations on the quasistatic and dynamic material behavior of concrete. Choosing a Soft Contact approach, a quite minimalistic constitutive law for particle interaction is used to model repulsion, cohesion and viscous damping. Since particle size differs significantly, the well-known Linked Cells strategy has to be modified in order to handle the computational effort.

At its earliest stage of lifetime, concrete is not the solid material known to be the most commonly used material for massive construction. Fresh concrete behaves like a fluid or granular matter. It is not until hardening, when the *liquid stone* obtains its shape, stability and mesoscopic structure.

The mesoscopic structure of concrete affects its macroscopic behavior. Crack evolution and damage behavior cannot be fully understood without considering the material's heterogeneity. Strain rate effects and other phenomena affecting its dynamic behavior are strongly based on the shape, geometry and distribution of aggregates inside the cementitious paste.

Real experiments 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. As a first approach they can be generated as dense packings of spherical aggregates with particle size distributions that are based on conventional sieving lines for concrete. They may be used for both Finite Element and, as will be shown, particle-based methods like the Discrete Element Method. Typical specimens are of cubic, cylindrical or prismatic shape while other geometries are possible as well.

Each individual specimen may be used for numerous loading situations, uniaxial or multiaxial, monotonic or cyclic – even for situations that cannot be realized in the laboratory for practical reasons. It is possible to generate virtual specimens that consist of an identical ensemble of aggregates, but differ in their arrangement. Such *clones* can help to estimate the influence of distribution and arrangement of aggregates on the material and damage behavior of hardened concrete.

An outlook will be given on how densely packed ensembles of spherical virtual aggregates may be used in order to generate more realistic packings of particles of polyhedral shape.