Size effect in concrete under tensile splitting - experiments and DEM analyses for different failure modes

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ABSTRACT

A size effect is a fundamental phenomenon in concrete materials. It denotes that both the nominal structural strength and material brittleness (ratio between the energy consumed during the loading process after and before the stress-strain peak) always decrease with increasing element size under tension [1]. Thus, concrete becomes ductile on a small scale and perfectly brittle on a sufficiently large scale. Two size effects are of a major importance: energetic (or deterministic) and statistical (or stochastic) one. In spite of the ample experimental evidence, the physically based size effect is not taken into account in practical design rules of engineering structures, assuring a specified safety factor with respect to the failure load. Instead, a purely empirical approach is sometimes considered in building codes which is doomed to yield an incorrect formula since physical foundations are lacking.

Our main objective is to experimentally and theoretically investigate a size effect in concrete under tension for different failure modes. Several splitting tensile laboratory tests were carried out with four different concrete specimen diameters (5-25 cm). The concrete cracking was observed by means of a x-ray micro-tomography using the micro-tomograph Skyscan 117 [2]). The effect of the loading plate size was also investigated. The calculations were performed with the three-dimensional spherical discrete element model (DEM) YADE which was developed at University of Grenoble [3]. This 3D spherical discrete element method takes advantage of the so-called soft-particle approach (i.e. the model allows for particle deformation which is modelled as an overlap of particles). Concrete was depicted as a four-phase composite materials including aggregate, cement matrix, interfacial transitional zones (ITZs) and macro-voids [4], [5]. The shape and location of aggregate particles and macro-voids were taken based on μCT-images. The process of micro- and macro-cracking was studied in detail for different specimen diameters including a various material behaviour (quasi-brittle, brittle and snap-back). The global stress-CMOD curves and crack shapes were directly compared with the laboratory outcomes. A satisfactory agreement with experiments was obtained. In addition, the evolutions of normal contact forces, normal and tangential displacements, porosities, particles rotations were carefully studied at the aggregate level. A special attention was paid to the evolution of internal energies.

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