Discrete modeling of concrete failure and size-effect

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Size-effect in concrete and other quasi-brittle materials defines the relation between the nominal strength and structural size when material fractures. The main cause of size-effect is the so-called energetic size-effect which results from the release of the stored energy in the structure into the fracture front. In quasi-brittle materials and in contrast to brittle materials, the size of the fracture process zone is non-negligible compared to the structural size. As a consequence, the resulting size-effect law is non-linear and deviates from the response predicted by linear elastic fracture mechanics. In order to simulate the size-effect, one needs to rely on numerical modeling to describe the formation, development and propagation of the fracture process zone. Although a number of models have been proposed over the years, it transpires that a correct description of the fracture and size-effect which accounts for boundary effects and varying structural geometry remains challenging. In this study, the Lattice Discrete Particle Model (LDPM) [1] is proposed to investigate the effects of structural dimension and geometry on the nominal strength and fracturing process in concrete. LDPM simulates concrete at the aggregate level and has shown superior capabilities in simulating complex cracking mechanisms thanks to the inherent discrete nature of the model. In order to evaluate concrete size-effect and provide a solid validation of LDPM, one of the most complete experimental data set available in the literature [2] was considered and includes three-point bending tests on notched and unnotched beams. The model parameters were first calibrated on a single size notched beam under three-point bending and on the mechanical response under unconfined compression. LDPM was then used to perform blind predictions on the load-crack mouth opening displacement curves of different beam sizes and notch lengths. Splitting test results on cylinders were also predicted. The results show a very good agreement with the experimental data. The quality of the predictions was quantitatively assessed. In addition, a discussion on the fracturing process and dissipated energy is provided. Last but not least, the Universal Size-Effect Law proposed by Bažant and coworkers [3] was used to estimate concrete fracture parameters based on experimental and numerical data. The proposed approach and results were first presented in a recent conference [4] and were later published elsewhere [5].

References

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