Fracture of the concrete meso-structure: computed tomography, mesh generation and phase-field modelling

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ABSTRACT

Concrete is a complex heterogeneous material that, at the meso-scale, is composed of a cementitious matrix (mortar), aggregates, and pores. Its mechanical (in particular, fracture) behavior depends on both the mechanical behavior of the constituents and their geometric structure. It is by now well established that useful insight on the concrete behavior, especially with respect to crack initiation and propagation, fatigue, and interaction between fracture and transport, can be gained by its modeling and simulation at the meso-scale. In this work, phase-field models of fracture [1] implemented through the finite element method are adopted to study fracture of concrete at the meso-scale. Real meso-structures are obtained using computed tomography (CT), threshold-based segmentation and voxel-based mesh generation. While simplified, artificial geometries are commonly simulated in the literature, the present approach leads to an exact reproduction of a specific sample, hence it incorporates realistic aggregate shapes and allows for a comparison with experimental data on the same sample. A challenge in the application of the approach to real cementitious materials (as opposed to simplified artificial materials, see e.g. [2]) is segmentation of the CT data, due to the limited contrast among cementitious matrix and aggregates with similar absorption properties. An additional challenge is the very large number of degrees-of-freedom of the resulting computational model. In this work, we tackle both challenges, on one hand through the use of a recently proposed method based on contrast enhancers [3], on the other hand through parallelization and suitably preconditioned iterative solution schemes. In this presentation, we illustrate some significant examples leading to realistic fracture patterns in tension and compression (Figure 1). We also outline areas where the need for further research arises.

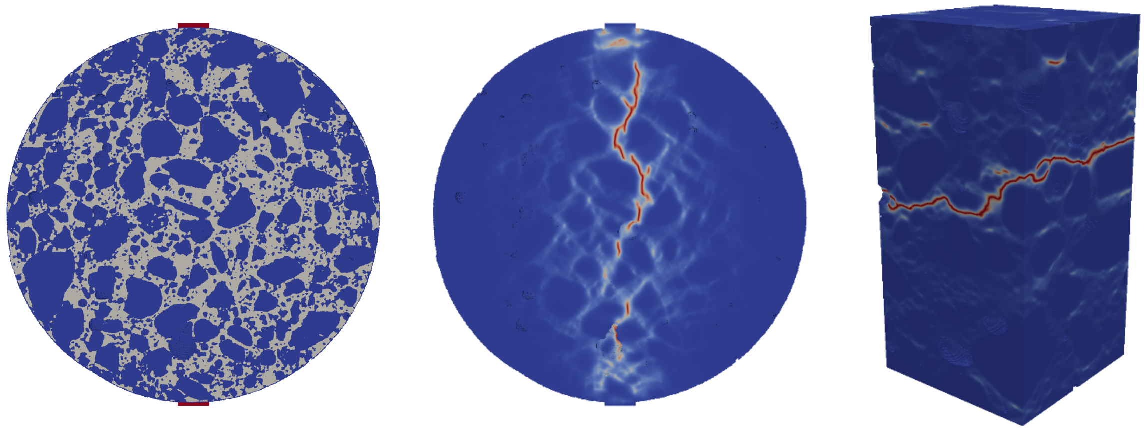

Figure 1: meso-scale structure of a concrete cylinder (left) and its fracture pattern upon vertical compression in the Brazilian test (center). Concrete in tension (right).

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