Modeling the cracking behavior of concrete at the mesoscale

A. Mishra[1]*, P. Carrara[1], M. Griffa[2], L. De. Lorenzis[1]

[1] Department of Mechanical and Process Engineering, ETH Zurich, Tannenstrasse 3,8092 Zurich, Switzerland, {amishra, pcarrara, ldelorenzis}@ethz.ch
[2] Concrete and Asphalt Laboratory, Empa, Swiss Federal Laboratories for Materials Science and Technology, Überlandstrasse 129, 8600 Dübendorf, Switzerland, Michele.Griffa@empa.ch

Crack nucleation and propagation in composite materials like concrete is largely influenced by their mesostructural arrangement. It is nowadays widely accepted that a substantial advancement in understanding their behavior can be gained by modeling explicitly their mesostructure, i.e. by resolving the heterogeneities within the matrix. To obtain realistic 3D geometries an increasingly adopted technique is X-ray computed tomography (CT) [1], which has recently seen great improvements in terms of both spatial and temporal resolution. This technique delivers a large amount of data not only regarding the real mesoscopic arrangement of the phases but also about the crack onset and 3D complex propagation pattern during a mechanical test. The latter information can be obtained from in-situ testing, i.e. by taking several CT images of a sample at different stages of a mechanical test, and from their analysis using Digital Volume Correlation (DVC) to measure the 3D displacement field [4].

The phase-field approach to brittle fracture [2] is a flexible model able to reproduce a broad range of fracture processes including crack nucleation, propagation, branching and merging without introducing ad-hoc criteria. This approach regularizes a sharp crack through the introduction of a phase-field parameter that smoothly varies between 0 (sound material) and 1 (completely cracked) over a support whose width is governed by a small length scale parameter.

The aim of this work is to calibrate and validate the phase field model for brittle fracture of the cement mortar to reproduce the cracking behavior of real concrete at the mesoscale, namely, where an appropriate fraction of aggregates and pores are explicitly resolved. To this end, experimental tests are performed to characterize the elastic and the fracture parameters of both mortar and aggregates. To obtain a validation dataset, a series of in-situ wedge splitting tests [3] is performed on concrete specimens doped with baryte contrast enhancers to enable the automatic segmentation of aggregates and matrix [1]. The CT image of the specimen before loading delivers the real mesoscopic 3D geometry, while from DVC analysis on the time series of images we obtain realistic boundary conditions that can be used as input in the numerical analysis. Also, the adopted procedure provides the 3D evolution of the crack pattern and a full-field displacement dataset. Finally, the calibrated model is validated by comparing numerical and experimental results.

References

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