Modeling of fracture in highly heterogeneous materials

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Abstract

In recent years, the fast development of 3D imaging techniques such as micro tomography combined with in-situ testing have offered new possibilities to investigate the microstructural damage evolution due to microcracking of highly complex materials such as concrete [1] or regular lattices obtained by additive manufacturing (3D printing). These new experimental and manufacturing techniques open tough challenges for the modeling of damage in heterogeneous quasi brittle materials: simulate the initiation and propagation of complex 3D micro crack networks in realistic geometries arising from micro tomography, identify the microstructural damage models, construct damage models at the scale of homogeneous materials, or even optimizing the local topology of constituents to maximize the resistance of the material to fracture.

In a first part [2-6], we present recent results of microcracking numerical models in realistic concrete microstructures obtained by combining micro tomography, 3D imagery, in-situ testing, and the numerical phase field method to fracture [7,8]. We show that this method combines several advantages in this context: (a) the possibility to simulate the initiation and propagation of complex micro crack networks in realistic geometries of microstructures; (b) no mesh dependence, allowing using directly regular meshes obtained from segmented images; (c) a very small number of parameters to be identified; (d) a high robustness and efficiency of algorithms. We present the first, to our best knowledge, direct comparisons between 3D complex evolving crack networks obtained from experiments and simulations at both micro and macro scales in plaster and concrete samples [3]. An identification of microstructural damage parameters based on inverse approaches combining in-situ testing, 3D imaging, 3D image correlation and the numerical phase field method for fracture is presented.

In a second part [9,10], we describe an approach to design complex 2-phase lattice materials which can be obtained by recent 3D printing techniques to maximize their fracture resistance to microcracking [7,8]. The method uses topology optimization combined with full simulations of micro cracks initiation and propagations in heterogeneous periodic lattice structures. At each iteration of the procedure, the topology of local geometries is optimized for maximizing the total fracture energy of the material, by taking into account both bulk and interfacial damage between phases. Finally, a method to construct simplified models of damage description at the scale of the homogeneous materials in these regular lattice materials is proposed.

References

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Acknowledgements

This work has benefited from a French government grant managed by ANR within the frame of the national program Investments for the Future ANR-11-LABX-022–01.

The financial support from IUF (Institut Universitaire de France) is gratefully acknowledged.