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FRACTURE PROCESS ZONE EVOLUTION IN THE COURSE OF FAILURE IN QUASI-BRITTLE MATERIALS: NUMERICAL INVESTIGATIONS AND EXPERIMENTAL VALIDATIONS AT THE MESOSCALE

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Fracture of quasi-brittle materials such as concrete or rocks is characterized by a macro crack surrounded by a damage zone. At the tip of the macro crack and ahead lies the so-called Fracture Process Zone (FPZ) which is a region of the material undergoing distributed damage. The size of the FPZ in these heterogeneous materials is large enough to influence the mechanical behaviour of the structure significantly. It does not depend on the structural size, but it is rather controlled by the local heterogeneities in the material as well as by the geometry of the specimen and the stress conditions. Therefore, size effect, understood here as the dependence of the dimensionless nominal strength of a structure on its size, is observed.

As far as modeling is concerned, continuum based approaches and discrete or mesoscale models are available. The first one involves a characteristic length which controls the size of the FPZ. In recent models, however, it has been pointed out that this internal length is not constant during the fracture process and also that it is influenced by boundaries, which could be expected since experimental works on fracture in concrete underline the influence of boundaries on the fracture energy. The second approach relies on a mesoscale description of the material and on an explicit description of the heterogeneities in the material. As opposed to the continuum approach, mesoscale models do not introduce any characteristic length. At the scale of a lattice element or a discrete element, softening is introduced as a local property.

Recently, Grassl and coauthors [1] demonstrated that mesoscale modeling was very efficient at describing not only size effect on the peak load, but also the entire load deflection response of bending beams. Four geometrically similar sizes and three different notch lengths were considered. The experimental data obtained by Grégoire and coauthors [2] could be quite accurately described, once the model parameters at the mesoscale level had been calibrated for one notch length. In addition, the authors used this model for studying the incremental distribution of the dissipated energy densities, and they were able to track the evolution of the FPZ in the structure, depending on the size of the beams and on the boundary conditions.

Experimentally, the damage zone may be characterized with the help of several direct and indirect techniques. The localization of acoustic events (AE) that can be detected during crack propagation is one well established technique from which the FPZ can be visualized and characterized. Hence, this technique provides information on the entire crack propagation process composed of distributed micro cracking and further coalescence into a macro crack.

The purpose of this paper is to provide a further insight in the description of failure (i.e. in the FPZ evolution) in quasi-brittle materials, with the help of statistical analyses of damage. The statistical analysis relies on the implementation of Ripleys functions [3], which have been developed in order to exhibit patterns in image analyses. Particularly, these functions allows the characterization of the randomness of a point distribution. Therefore, for a given repartition of micro-cracking within the structure, a correlation length between damage events may be identified as the deviation of the Ripley's functions from a pure random distribution. It is shown how this correlation length is connected to the fracture process zone and how it evolves in the course of failure. Mesoscale numerical tension tests are first presented in order to show the possibilities of the method. Then, three points bending tests on notch and unnotched geometrically similar specimens are performed in a way to study the FPZ evolution depending on size and boundary effects. Comparisons with AE experimental data are performed to validate the numerical results.

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