Influence of material heterogeneities on crack propagation statistics using a Fiber Bundle Model

François VILLETTE[†], Julien BAROTH[†], Frédéric DUFOUR[†*], Jean-Francis BLOCH[†] and Sabine ROLLAND DU ROSCOAT[†]

[*] [†] Univ. Grenoble Alpes, CNRS, Grenoble INP, 3SR, F-38000 Grenoble, France
Laboratoire 3SR, Domaine universitaire BP53
38041 GRENOBLE CEDEX 9 France
Email : francois.villette@3sr-grenoble.fr

ABSTRACT

The problem of damage in heterogeneous materials has received particular attention in recent years. Indeed, the numerical models currently used in the simulation of damage in materials require an internal length that is not currently related to a characteristic length of the material components. The heterogeneities in the materials are of different sizes (sand, gravel for concrete for example). The largest is commonly accepted as having the greatest influence on the propagation of the crack. This length can correspond to the size of the largest heterogeneities but also to the distance between them. The problem of the length to be put in the models therefore remains an open question. However, understanding damage as a function of the size of the heterogeneities is of crucial importance, particularly in civil engineering, for the durability of structures.

The Fiber Bundle Model [1] has been developed and widely used in the few past decades to qualitatively address the issue of damage in heterogeneous media by studying the statistics of failure events during damage. In this model, the material consists of a 1D set of tensile fibers that break successively in greater or lesser numbers during traction, known as "rupture event" or "fiber rupture avalanche". This model was extended into the so-called ZIP model changing the geometry of the bundle adding a shape of the displacement field imposed on fibers mimics crack tip a few years ago to study statistics during crack propagation [2]. In the applications of these models, if the heterogeneities of the material are represented by a "white noise" within the spatial distribution of the tensile strength of fibers, no application involves a characteristic length of microstructure.

In this work, a spatial correlation of tensile strength of fibers is added to the ZIP model to highlight the role of heterogeneity size in statistics of failure events during crack propagation in a material with a microstructure. The tensile strength of fibers is modelised by a spatially autocorrelated random process. The Karhunen-Loève decomposition is applied to the covariance function.

The addition of microstructure to the crack propagation problem with the ZIP model shows a significantly different distribution of failure events than that obtained for a simulation with a material without microstructure. Indeed, it has been demonstrated that for a material without a microstructure, failure events follow two regimes at two different scales [2]. By adding a microstructure to the material, a transitional regime appears. The transitional regime characteristics have been studied for different sizes of the microstructure and the displacement field. It has been shown than the influence of the microstructure on fiber rupture avalanche strongly depends on the ratio between the sizes of the shape of the stress field and heterogeneities highlighting a size effect.

This work highlights the importance to take into account both the microstructure and the size effect due to the stress field in numerical modelling. The study of the transitional regime gives results over scales affected during cracking by microstructure knowing its size and the size of the stress field shape.

REFERENCES

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