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MACROSCOPIC PROBABILISTIC MODELLING OF CRACKING PROCESSES IN CONCRETE STRUCTURES

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ABSTRACT

The development of models providing information on the characteristics of concrete cracks, for a given environment, loading and limit conditions set, is actually very popular. Cracks openings, lengths, orientations and spatial distributions are essential factors. Their impact on the long term structural performance maintenance must be taken into account for an accurate prediction of structures life span.

Macroscopic continuous models are often preferred by engineers for modelling the behaviour of structures : their theoretical frameworks (most often the thermodynamics of irreversible processes) are well established. The chosen macroscopic parameters, variables, potentials or evolution laws have, generally, some evident physical meanings. Their numerical implementation in the finite element method context is quite “natural” and robust solving algorithms are now available. But, although these models are more and more sophisticated and relatively appropriate to represent the macroscopic mechanical behaviour of concrete structures, they are not fully pertinent for providing information on the characteristics of cracks. Difficulties appear in the link which must be set up between the local description of the mechanisms at the material level and the global response of the structure, essentially when one try to combine them through a robust and reliable modelling.

The paper proposes an original approach for modelling the cracking of cementitious composites structures. The first objective of the model is, of course, to be able to efficiently perform numerical simulation of concrete structures behaviours. A robust framework is then chosen. And only monotonic loading is considered here. The second objective is to account for the material heterogeneity as one of the main factor influencing concrete cracking processes. A probabilistic approach, largely drawn from the Rossi’s probabilistic model [1] and considering some mechanical characteristics as random parameters [2], is used. The third objective is to determine cracks characteristics such as those cited above (openings, spatial distributions,...).

Classically, finite elements define elementary volumes of material. In this model, the cracking behaviour of these elements is represented by an “equivalent” material behaviour following simple perfect elastic-plastic laws and entirely dissipating the whole necessary energy. Basic oriented criteria (Tresca) are used

in tension or shear loading to initiate cracking processes in some direction. They can be replaced by a classical Mohr-Coulomb criterion when cracks are set up. When the entire energy is dissipated, a zero stress level is maintained in the element, considered as being completely cracked. The determination of the behaviour needs by nature to account for the scale of the stressed material volume. Even at the scale of the element. With this intention, behaviours of different material volumes are first simulated under axial loading – tension and compression for the moment. Simulations are performed using the Rossi's probabilistic discrete model. A statistical analysis of the results is performed. The mechanical pre- and post-peak behaviours of the material, as well as cracking, are analysed. Mean values and standard deviations of parameters such as the Young's moduli, the tensile stresses and also dissipated energies can be determined for the considered volumes of material (the other parameters can be differently obtained using mechanical considerations developed in [3]). Then, varying stressed volumes, volume effects laws can be derived from this analysis for these parameters. Note that cracks opening are also analysed. In a second stage, the results of this broad numerical experimentation are used to determine the parameters of the "equivalent" elastic-plastic model. As stated above, this equivalence is performed using an energetic equivalence. A parallel between the macroscopic strain and the opening of cracks is also drawn in this model. Finally, some numerical example are shown illustrating that this model can be considered as an efficient macroscopic description of discontinuous cracking processes in concrete.

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