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TRANSITION FROM DISTRIBUTED TO LOCALIZED CRACKING IN QUASIBRITTLE MATERIALS

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The cohesive crack model is a relatively simple and accurate means of describing fracture of quasibrittle materials, such as concrete, ceramics and rocks. In applications, it is often assumed that all the material surrounding a main cohesive crack remains linear elastic. However, detailed analyses show that if no strong stress concentrators initially exist (sharp notches, e.g.), the tensile strength is exceeded within the supposedly elastic region, which means that secondary cracking must occur [1].

Recent experimental and numerical work on cover cracking of concrete due to rebar corrosion shows that several well developed secondary cracks form around the bar, and the numerical model indicates that there is a relatively smooth transition from a finely distributed cracking around the bar to a fully localized pattern [2].

In the present contribution, the authors analyze the reliability and robustness of the method proposed in [3, 4]. Analyses for an unnotched beam of concrete in three-point bending show that, initially, cracking is distributed over the central zone of high tensile stress, then, as the load approaches the peak, one or two cracks become dominant, and, at peak load, only one of the cracks prevails. The measurable results (load-elongation curve) are shown to be basically independent of the mesh size and of the step size.

The independence of the step size has been also demonstrated for a slab subjected to a highly idealized shrinkage process in which the fully constrained shrinkage stress at the exposed surface, σ_0, increases from 1.0 to 4.0 times the tensile strength f_t, while keeping the stress profile linear and self-similar. The results for 30 steps ($\Delta\sigma_0 = 0.1 f_t$) show that, initially, a nearly uniform distribution of tiny cracks appears, as shown in Figure 1(a) for $\sigma_0 = 1.5 f_t$ where a few slightly more prominent cracks can already be seen. For $\sigma_0 = 4 f_t$, Figures 1(b)-(c) show, for widely different step sizes, that about seven mean cracks have been formed and most of the distributed cracking has disappeared, while a few small secondary cracks still survive; although the three pictures look very similar, the details of the crack location and extension do slightly vary with the step size.

As a main conclusion, the method is basically insensitive to mesh and to step size as long as global behavior is concerned, and robust, since it comes to a solution for any step size; however, the details of the localization do depend on the mesh and on the step size.

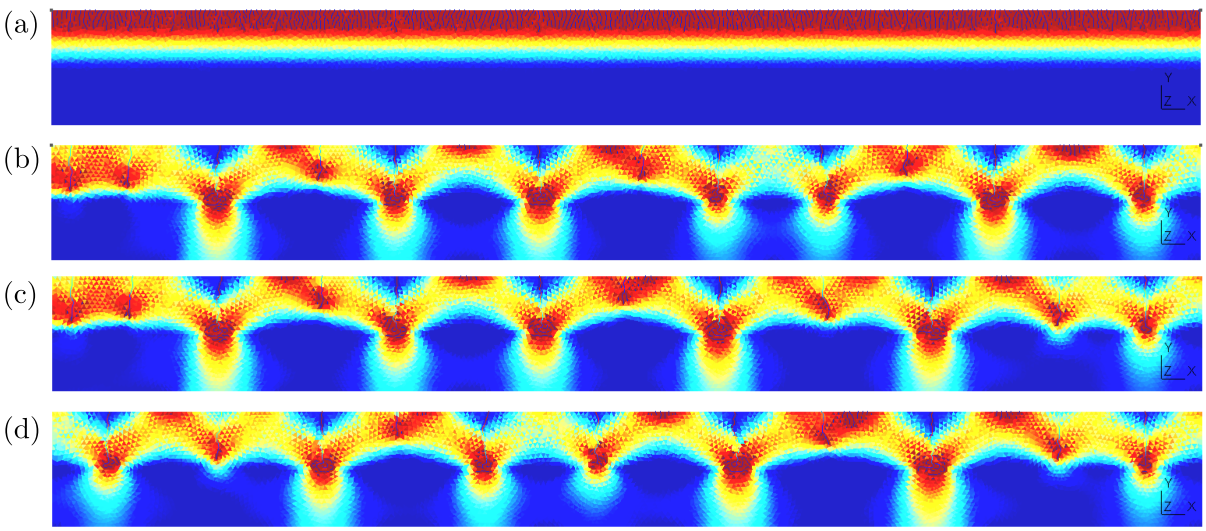

Figure 1: Crack patterns and distribution of maximum principal stress for various shrinkage levels and step size (a) $\sigma_0 = 1.5 f_t$, $\Delta\sigma_0 = 0.1 f_t$; (b) $\sigma_0 = 4 f_t$, $\Delta\sigma_0 = 0.1 f_t$; (c) $\sigma_0 = 4 f_t$, $\Delta\sigma_0 = 0.5 f_t$; and (d) $\sigma_0 = 4 f_t$, $\Delta\sigma_0 = 1.0 f_t$. [Dark red: $\sigma_1 = f_t$; dark blue: compression.]

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