

Deterministic Size Effect in the Strength of Cracked Quasi-Brittle Structures

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This paper is concerned with the quantification of the deterministic (as opposed to the statistical) size effect in the strength of cracked quasi-brittle structures. This effect is believed to be a result of stress discontinuities and redistribution introduced by the cracks. Quasi-brittle materials are characterized by the presence of a large fracture process zone (FPZ) ahead of a crack in which the material softens. The FPZ is captured within a nonlinear theory of fracture in the so-called fictitious crack model (FCM) which has its origin in the Barenblatt-Dugdale cohesive zone concept. In the FCM, the FPZ ahead of a real crack is replaced with a fictitious crack in which the material exhibits softening described by a stress-crack opening relationship. As the size of FPZ can be commensurate with that of the structure, it is necessary to consider not only the singular term in the asymptotic field at the real crack tip but also higher order, non-singular terms, in order to describe stress distribution in the FPZ. This necessitates determination of these higher order terms, as well as of the required weight functions for finite size specimens that can be tested in a laboratory. This has been done in present work. The results of this theoretical work have been found to be in excellent agreement with test data in the limited range of sizes tested in the laboratory. The theoretical results have been extended to cover the very large size range of 1:80. Based on these results, a deterministic strength size effect formula that is very simple to use in the size range 1:80 has been proposed. In agreement with experimental observations, this formula predicts that the deterministic strength size effect weakens as the size of the crack reduces relative to the size of the structure but it becomes stronger as the size of the structure increases but never stronger than that predicted by linear elastic fracture theory.

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