Chapter 3
Fracture Behavior of Concrete using Cohesive Crack and Size-Effect Models

3.1 Introduction

This chapter gives an idea of the nonlinear fracture behavior of concrete using cohesive crack and size-effect models. Initially, the formulation and development of cohesive crack model for three-point bending test and compact tension specimen are presented. Then a systematic study on the several cohesive crack fracture parameters for the TPBT and CT specimen with various softening functions is carried out. Toward the end, with reference to cohesive crack model, the size-effect study from size-effect law is investigated using three-point bending test. The contribution in this chapter is mainly based on work done by Kumar (2010) and Kumar and Barai (2008, 2009).

3.2 Cohesive Crack Model for Three-Point Bending Test

3.2.1 Formulation Based on Energy Principle

Assuming that under condition of proportional and monotonic loading in mode I crack propagation, no unloading occurs in the fracture process zone and the process zone boundary can be defined by only one variable, i.e., the crack length a. The potential energy Π of a cracked body as shown in Fig. 3.1 is written as (Li and Liang 1994)

$$\Pi\,(u_i, P, a) = \int\limits_V W(\varepsilon_{ij})\mathrm{d}V - \int\limits_V F_i u_i\,\mathrm{d}V - P\int\limits_{A_\mathrm{T}} b_i u_i\,\mathrm{d}A + \int\limits_{A_\mathrm{P}} \phi(w)\mathrm{d}A \qquad (3.1)$$

where W is the strain energy density function defined in the body, ε_{ij} is the strain field, F_i is the body force, u_i is an admissible displacement field for the system, b_i is the boundary force distribution defined in the part of boundary A_T. The potential ϕ can be defined for any given cohesive law $\sigma = f(w)$ as

S. Kumar, S.V. Barai, *Concrete Fracture Models and Applications*,
DOI 10.1007/978-3-642-16764-5_3, © Springer-Verlag Berlin Heidelberg 2011

stress in the process zone. The basic feature of cohesive crack model is represented by Eq. (3.5). The equation states that the algebraic summation of stress intensity factors at the crack tip due to the external loading, constant body force, boundary force, if any and the cohesive stress distribution in the process zone is zero. This statement eliminates the stress singularity at the crack tip of the structure and a finite stress acts near the crack tip.

3.2.2 Basic Assumptions

The following assumptions are considered in the development of cohesive crack model (Petersson 1981, Carpinteri 1989a–c, Carpinteri and Colombo 1989, Carpinteri et al. 2006):

1. The bulk of material behaves in a linear elastic and isotropic manner.
2. The cohesive process zone begins to develop when the maximum principal stress becomes equal to the tensile strength.
3. The material is in partially damaged condition and is still able to transfer the stress known as cohesive stress σ after formation of cohesive fracture zone. The cohesive stress depends on the crack opening displacement w. For mode I opening, σ acts normal to the crack faces as shown in Fig. 3.2 and is related to w as below:

$$\sigma = f(w) \tag{3.6}$$

Also from the definition of softening function of concrete

$$f_{\mathrm{t}} = f(0) \tag{3.7}$$

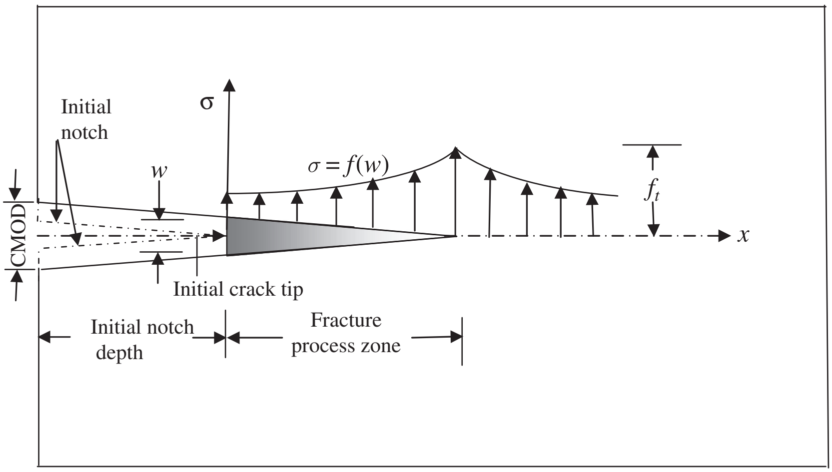

Fig. 3.2 Stress distribution and cohesive crack growth in mode I opening for concrete

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http://www.springer.com/978-3-642-16763-8

Concrete Fracture Models and Applications
Kumar, S.; Barai, S.V.
2011, XXII, 262 p., Hardcover
ISBN: 978-3-642-16763-8