Chapter 5
Fracture Properties of Concrete Based on the K_R Curve Associated with Cohesive Stress Distribution

5.1 Introduction

This chapter is attributed to the previous works carried out by Kumar and Barai (2008a, b, 2009a–c, 2010) and Kumar (2010) in which mainly the application of *weight function method* is introduced to determine the K_R curve associated with the cohesive stress distribution in the FPZ. Experimental data (Roesler et al. 2007) available in the literature are used to validate the weight function approach for determining the K_R curve and the results are analyzed to study the instability criteria using the K_R-curve method. Finally, the influence of specimen geometry, loading condition, size effect, and softening function of concrete on the K_R curve and the related fracture parameters is carried out for which the load-crack opening displacement curves are obtained using the FCM.

5.2 The K_R-Curve Method

The K_R-curve method based on cohesive stress distribution in the FPZ introduced by Xu and Reinhardt (1998, 1999) and Reinhardt and Xu (1999) for complete fracture process description of concrete differs from the conventional method of the R curve. The distribution of cohesive stress along the FPZ at different stages of loading conditions is taken into account in order to evaluate the K_R curve. In addition, the double-K fracture parameters are introduced in the stability analysis using the K_R curve. During crack propagation, the contribution of cohesive toughness increases with the increase in process zone length that depends upon cohesive stress distribution σ which is a function of crack opening displacement w, tensile strength of concrete f_t, and the propagating crack length a. At the onset of unstable crack propagation, the stress intensity factor K at the tip of the propagating crack is expressed as

$$K = K_R(\Delta a) \tag{5.1}$$

where $K_R(\Delta a)$ is the crack extension resistance at crack extension length $\Delta a = a - a_o$. Also, the crack extension resistance $K_R(\Delta a)$ can be expressed with the following relation:

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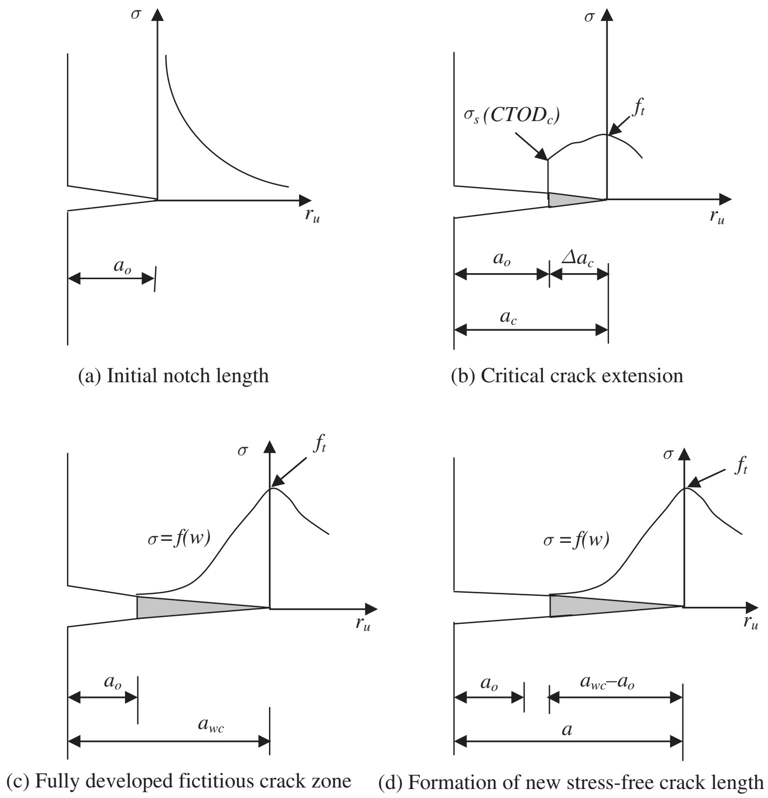

Fig. 5.2 Four stages of crack propagation during the fracture process

$$K_I > K_{IC}^{un} \quad \text{The crack propagates unsteadily}$$

In order to develop the K_R curve for complete fracture process considering the cohesive stress in fictitious fracture zone, it becomes important to determine the value of cohesive toughness K_I^{COH} at every stage of loading on the structure. During the crack propagation, four different loading conditions are considered using three characteristic crack lengths (a_o, a_c, and a_{wc}) as illustrated in Fig. 5.2.

The figure shows the development of cohesive stress distribution during crack initiation and crack growth in fracture process of concrete. With the increase in the fictitious fracture zone from Fig. 5.2a–d, the undamaged length of the ligament r_u decreases. Figure 5.2a represents the first stage of loading in which the external loading on the structure is still less than P_{ini} and the material ahead of the initial crack tip still behaves in a linear elastic manner. In this case, the stress near the crack tip tends to be singular and the classical form of linear elastic fracture mechanics is applicable. As the external loading is equal to the value of P_{ini}, the stable crack begins to form. Further, when the load increases, the stable crack propagation begins

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