CHAPTER 1

INTRODUCTION

1.1 General

Fracture is a problem that society has been facing since there were man-made structures. However, much attention was not paid to the problem until the brittle fracture of Liberty ships that were the first to have an all-welded hull. A significant number of the ships broke into 2 parts or experienced serious damages. The reason of its appearance was that the newly all-welded design method was used (Bannerman and Young 1946). It was also revealed that the Liberty ship failures were caused by a combination of three factors: the welds contained crack like flaw, there was a local stress concentration at most of fractures at square hatch corners, and the steel used had poor toughness. Therefore, a group of researchers at the Naval Research Laboratory in Washington D.C. studied the fracture in detail. Much more attention has been paid to fracture mechanics since then.

Fracture mechanics is the subject that deals with studying the behavior of cracks in materials. By definition, fracture mechanics is a method of characterizing the fracture behavior by structural parameters that can be used directly by engineers, for example, stress and flaw size. The classical benefit of fracture mechanics, listed by Broek (1982), is to answer the following questions:

1. What is the residual strength as a function of crack size?
2. What size of crack can be tolerated at the expected service loads; that is, what is the critical crack size?
3. How long does it take for a crack to grow from a certain initial size to the critical size?
4. What size of pre-existing flaw can be permitted at the moment the structure starts its service life?
5. How often should the structure be inspected for cracks?

Fracture mechanics provides satisfied answers to some of these questions and useful ones to the others. At the early age of fracture mechanics, the development of the application of the subject was limited to metals. Later, there were attempts to take advantage of the subject to explain the behavior of concrete and other quasi-brittle materials. Many models have been proposed and developed by many researchers. For example, Hillerborg (1976) first proposed a fictitious crack model to predict the nonlinear behavior ahead of crack tips in concrete. Bazant and Oh (1983) proposed a model called crack band model that was the fundamental of the smeared crack model. Although these models can reasonably give accurate results for various types of problems, they are not able to cover overall behavior of problems that include cracking localization which occurs in quasi-brittle materials. The reason is simply because the phenomenon is not considered in the models. This insufficient consideration in these models leads to inaccurate prediction of the fracture behavior of concrete and other quasi-brittle materials at peak and post peak load. To illustrate the importance of the consideration of cracking localization in concrete, let us consider the uniaxial tension test shown in Figs. 1.1 and 1.2. By employing the strength criteria, the crack will distribute over the specimen as shown in Fig. 1.1. However, it is contrast to the actual behavior that only one discrete crack will finally open while others will close as shown in Fig. 1.2. Having many cracks without the localization allows more energy to dissipate from the domain than when one or few localized cracks are considered. Therefore, neglecting the cracking localization in such a problem will certainly result in significant error.

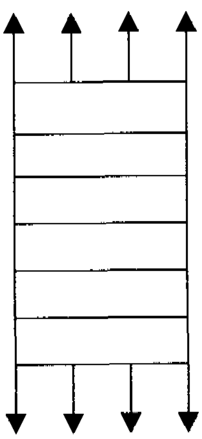

Fig. 1.1 Crack with no localization

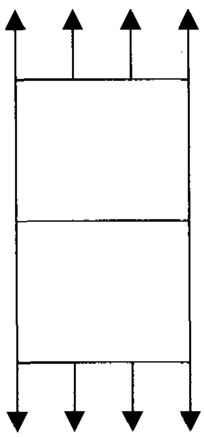

Fig. 1.2 Crack with localization

Many researchers have proposed theories of the localization (Nguyen 1987, Bazant 1989, Valente 1992, and Horii and Okui 1995) and applied those theories to their analysis. However, the important obstacle to their analysis is the nature of the analysis of this type. The analysis will be massive and complicated. Because of this, many researchers try to avoid the consideration of the cracking localization by either allowing many cracks to grow without any consideration of the localization or assuming the positions of the localized cracks. The first approach is not realistic and can lead to very inaccurate results. Only in some cases where the stress gradient of the problems is very large, the localized solution may be obtained from this approach if the stress cracking criterion is used. When the stress gradient is very high, it is possible that major cracks will finally prevail and the other cracks will undergo the elastic unloading. This is due to big difference in the magnitudes of stress between different locations. The second approach, which assumes the positions of the localized cracks prior to the analysis, can yield reasonable results if the assumed positions of the localized cracks are reasonably correct or if the required solutions, such as the ultimate loads, are not sensitive to the positions of the localized cracks. However, this approach is not appropriate for general cases where the locations of localized cracks may not be easily predicted.

It can, therefore, be clearly seen that efficient methods to tackle the problems of cracking localization are very necessary. In this study, an efficient analysis method will be developed. The proposed method will employ the finite element method as a base numerical analysis method due to its efficiency.

1.2 Objectives

1. To develop a numerical analysis method for problems involving cracking localization in quasi-brittle materials.
2. To investigate cracking localization problems in quasi-brittle materials by employing the obtained analysis method.

1.3 Scope of Study

1. Only quasi-brittle materials will be considered.
2. Only two-dimensional problems will be considered.
3. The finite element analysis method will be used as a base numerical method for the development of the analysis method.