

Fracture Mechanics of Concrete Structures

Volume 1

**Fracture Properties and Parameters**

Edited by

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and  
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## PREFACE

"Fracture mechanics," in its broad aspects, represents an applied mechanics framework which is necessary for describing the behavior of cracked components under applied loads. Since the pioneering paper of Griffith in 1920, fracture mechanics has been applied to various kinds of materials and components. Nowadays it has been an important branch of engineering field. Although fracture mechanics was also applied to concrete and concrete structures in the beginning of 1960s already, most of engineers and even scientists were not convinced of the applicability.

Concrete is a kind of composite and very heterogeneous material. Consequently cracks are arrested when they encounter aggregates, and a large fracture process zone is developed in front of the main crack. That is the reason why the classical concept of fracture mechanics is not applicable to concrete, and some new concepts need to be developed. It was A. Hillerborg who performed the breakthrough. He proposed a model that became wellknown as "fictitious crack model" later, which represents a relation between transmitted stress over narrow crack and crack width (Hillerborg, A. et al. 1976, Cement and Concrete Research). This was the first idea of strain softening diagram for concrete under tension. The area under the diagram was defined as a fracture property which was called "fracture energy  $G_F$ " later.

In 1978, the first international technical committee on fracture mechanics of concrete was set up in RILEM (TC 50-FMC, chaired by F.H. Wittmann). This technical committee published a comprehensive state-of-the-art report together with the annotated bibliography (Wittmann, F.H. (ed.) 1983, Fracture Mechanics of Concrete, Elsevier), and recommended the test method to determine  $G_F$ . Then in 1985, the first international conference on fracture mechanics of concrete was organized by F.H. Wittmann in Lausanne.

Since then, the main subjects in fracture mechanics of concrete have been as follows: 1) What really occurs in the fracture process zone ? 2) Are there any parameters more suitable for fracture mechanics of concrete than  $G_F$  and what are the dominant factors influencing the parameters ? 3) How are the fracture process zone modeled, and how is the softening behavior numerically analyzed ? 4) Where and how could the nonlinear fracture mechanics be applied to concrete and concrete structures ? Size effect has been one of the noticeable topics.

From the beginning of 1980s, the research activities on fracture mechanics of concrete obviously increased and a number of papers on these subjects were published. While the number of international conferences on fracture mechanics of concrete increased after the middle of 1980s, Z.P. Bazant proposed to create an international association for remedying conferences held in disorder by arranging a series of the main conferences dealing with fracture mechanics of concrete. Thereby International Association of Fracture Mechanics of Concrete Structures (IA-FraMCoS) was founded and registered as a nonprofit organization in the State of Illinois in 1991. The name of the Association was changed to International Association of Fracture Mechanics for Concrete and Concrete Structures in the first general assembly meeting in 1992, while the abbreviated name remains as IA-FraMCoS. It was decided that FRAMCOS Conferences are organized at regular intervals (typically every three years), dealing with all aspects of fracture mechanics of concrete structures while changing sites among various continents and countries. The First International Conference on Fracture Mechanics of Concrete Structures (FRAMCOS-1) was held in Breckenridge, Colorado, U.S.A. in June 1992, organized by Z.P. Bazant. The Second International Conference on Fracture Mechanics of Concrete and Concrete Structures (FRAMCOS-2) was held in Zurich, Switzerland in July 1995, organized by F.H. Wittmann.

Besides these Conferences, three workshops ("Numerical Models and Material Parameters for Concrete Cracking" in Zurich 1992, "Size Effect in Concrete Structures" in Sendai 1993, and "Fracture and Damage in Quasibrittle Structures" in Prague 1994) were organized in cooperation with IA-FraMCoS. These Conferences and Workshops have shown that fracture mechanics of concrete is now one of the most exciting topics in the field of concrete engineering. Especially it is required to demonstrate how the fracture mechanics of concrete can be applied to solve the remained problems in the field of concrete engineering and design of concrete structures, and how it can contribute to their future development. Meanwhile real mechanisms in the fracture process zone have not been fully understood. "Generally accepted models" for mixed mode fracture and time dependent properties of cracking also have not been built up, yet.

The present proceedings of three volumes contain the invited and submitted contributions to the Third International Conference on Fracture



Mechanics of Concrete and Concrete Structures (FRAMCOS-3) held in Gifu, Japan during October 12-16, 1998. The main objectives of the Conference are to present the state-of-the-art and to discuss future directions of science and engineering associated with fracture mechanics of concrete and concrete structures. The volume 1 deals with "Fracture Properties and Parameters," the volume 2 refers to "Numerical Models and Analysis," and the volume 3 is on "Structural Applications and Size Effect." These volumes clearly show the applicability of fracture mechanics of concrete to engineering problems. They will serve as a valuable reference on the recent development in fracture mechanics of concrete and concrete structures.

All the submitted papers were carefully reviewed by members of the Scientific Committee and the Organizing Committee. It is our pleasure to thank all the authors for their excellent contributions and all the reviewers for their very kind collaboration. We would also express our thanks to Dr. N. Nomura, Mr. N. Itagaki, Mr. K. Kirikoshi and Miss R. Hashimoto of Tohoku University for their efforts to help us editing the proceedings.

In closing, the financial support by Japan Concrete Institute, the Kajima Foundation, Japan Prestressed Concrete Contractors Association and Gifu Convention Bureau is gratefully acknowledged.

May 1998

The Editors  
Hirozo Mihashi  
Keitetsu Rokugo



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# Fracture Properties and Parameters

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