

FRACTURE MECHANICS OF CONCRETE STRUCTURES

Proceedings of the First International Conference on Fracture Mechanics of
Concrete Structures (FraMCoS1) held at Beaver Run Resort, Breckenridge,
Colorado, USA, 1–5 June 1992

organized by

Northwestern University

in collaboration with the

NSF Science and Technology Center for
Advanced Cement-Based Materials (ACBM)

and the

ACI Committee 446 on Fracture Mechanics

under the auspices of the

International Association for
Bridge and Structural Engineering (IABSE)

and the

American Concrete Institute (ACI)

and sponsored by the

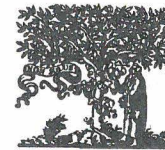
US National Science Foundation (NSF)

Edited by

ZDENĚK P. BAŽANT

*Walter P. Murphy Professor of Civil Engineering,
Northwestern University, Evanston, Illinois, USA*

1992



ELSEVIER APPLIED SCIENCE
LONDON and NEW YORK

PREFACE

Although fracture mechanics, originated by Griffith in 1921, is by now a mature discipline that has already found broad applications to metallic structures, the fracture mechanics of concrete structures is a young emerging theory. It will no doubt become very important for the design and evaluation of concrete structures, but has yet to be fully developed and verified. Research began with a pioneering experimental investigation of concrete fracture by M. F. Kaplan¹ and an equally pioneering finite element analysis of cracking in a concrete dam by R. W. Clough². But the progress was relatively slow through the 1970's and the opinion that fracture mechanics was not really applicable to concrete structures prevailed. This opinion, of course, pertained to fracture mechanics in either its linear form or the form of small-scale yielding known at that time. The attitude changed radically around 1980. It was realized that the fracture mechanics of concrete must take into account the large size of the fracture process zone which causes a pronounced R-curve behavior and, most importantly, gives rise to a strong size effect which is transitional between plastic limit analysis (no size effect) and linear elastic fracture mechanics (the strongest possible size effect). Because of the coarse heterogeneous microstructure of the material, many concrete structures are at the lower limit of the size effect transition, which permits their analysis according to plasticity theory. However, many large structures, especially nuclear reactor vessels or dams, or special structures such as those made of high-strength concrete, are in upper part of the size effect transition, which in effect dictates the use of fracture mechanics.

The research activity suddenly exploded at the beginning of the 1980's. Various committees of international societies devoted to the advancement of the subject were formed, the earliest being the RILEM committee chaired by F. H. Wittmann. After the conference in Lausanne in 1983, sponsored by Wittmann's committee, the number of conferences on the subject grew rapidly. During each of the last several years, there were many major international meetings and conferences dealing with concrete fracture, and they often conflicted with each other. This created a confusing situation. An active researcher was unable to attend all of these conferences, and at the same time he did not know which would be the principal one to choose. Realizing this state of affairs firsthand with my initial attempt at the scheduling of the present conference, I decided to discuss the situation with the leading researchers around the world. In summer 1990, I circulated a letter to the members of the freshly organized International Scientific Advisory Committee of this conference, in which I suggested that the disorderly spectrum of conferences could be remedied by organizing an international association that would run a series of the main conferences dealing with the subject, such that every active researcher would know well ahead of time which conference not to miss and where to present his best results.

The response was overwhelmingly supportive. It thus became clear that discussions of the details of founding an association were appropriate. I have held such discussions with a number of leading researchers, with whom I got a chance to meet, including S. P. Shah, F. H. Wittmann, H. Reinhardt, A. Carpinteri, H. Mihashi, L.

¹ "Crack Propagation and the Fracture of Concrete," ACI Journal, 58, 1961, No. 11.

² "Stress Distribution in Norfolk Dam," Department of Civil Engineering Series 100, Issue 19, University of California, Berkeley, 1962.

Cedolin, J. Mazars, J. Planas, K. Willam, B. I. G. Barr, R. de Borst, V. E. Saouma, J. van Mier, and others. We talked about it at the international workshop on concrete fracture held in Locarno, Switzerland, in September, 1990 (organized by Wittmann and Dugar) and the international workshop on concrete fracture held in Torino in October 1991 (hosted by A. Carpinteri). As a result of our discussions at these most charming locations, the detailed concept crystallized.

An organizing meeting was called to hotel Oranje in Noordwijk, Netherlands, where it was held on June 19, 1991, during a conference organized by J. van Mier. The International Association of Fracture Mechanics of Concrete Structures (IA-FraMCoS) was created by unanimous consensus of the members of the International Scientific Advisory Committee of this conference who were present in Noordwijk. They became the founding members. The president, the secretary and the steering committee members were elected on that day. The steering committee, headed by F. H. Wittmann and with B. I. G. Barr as secretary, is preparing the bylaws of our new Association, which will be voted on at this conference. It was decided to incorporate our Association in the state of Illinois and have the headquarters in Evanston. Mr. Clement J. Caroll, Jr., an attorney with Gordon & Glickson, a Chicago law firm, was hired to take care of the legalities of the incorporation as a non-profit organization, with the initial Board of Directors consisting of F. H. Wittmann, H. Mihashi and myself, as representatives of three continents. The incorporation was obtained from the State of Illinois on December 16, 1991, which lent our new Association legal status. The principal goal of our Association, run democratically by its members, will be to organize at regular intervals (typically every three years) FraMCoS Conferences, dealing with all the aspects of fracture mechanics of concrete structures. The sites should alternate among various continents and countries, with no geographic or other bias, however, favoring the main centers of research. If desired, our Association might also sponsor or co-sponsor various other symposia or workshops focused on more specialized subjects. Furthermore, it could serve to coordinate a calendar of meetings and promote the advancement and applications of fracture mechanics of concrete structures by other means.

As is clear from the present proceedings volume, an exciting program lies ahead of us in Breckenridge. There are many thought-provoking papers on difficult subjects, and also many questions still to be answered. Let us hope that the discussions at the conference will be lively and stimulating, not only the formal discussions at the sessions but also the private discussions during the free time, which is plentiful at this conference. There are reasons to believe we will make a good start and create a favorable climate for the subsequent conferences. The applications of fracture mechanics are important enough to require our most dedicated efforts.

It is proper for me to acknowledge my gratitude to the U. S. National Science Foundation for providing partial financial support for this conference. I wish to thank all the members of the Organizing Committee, and especially Professors K. H. Gerstle, V. E. Saouma, S. Sture and K. Willam of the University of Colorado, Boulder, and visiting scholar I. Carol, for their valuable help. I am grateful to the members of the International Scientific Advisory Committee for their advice. Thanks are also due to Milan Jirásek, Graduate Research Assistant at Northwestern University, for his expert assistance in preparing the present proceedings volume, and to Martha Moser for her general secretarial assistance. Furthermore, thanks are due to (1) the NSF Science and Technology Center for Advanced Cement-Based Materials at Northwestern University, (2) ACI and its Committee 446, Fracture Mechanics, and (3) International Association for Bridge and Structural Engineering for agreeing to co-sponsor this conference. Finally, I wish to thank the authors of the conference papers for their excellent contributions.

Zdeněk P. Bažant
President, IA-FraMCoS
Conference Chairman