
Fracture Mechanics of Concrete Structures

Volume III

Edited by
Folker H. Wittmann

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International Association of Fracture Mechanics of Concrete
and Concrete Structures

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with headquarters in Evanston, Ill., USA.

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Kampmann Gustav (1859-1917)

Drawings by Prof. Gustav Kampmann are reproduced on the cover page of all chapters. Kampmann was born in 1859 in Boppard, Germany. He studied at the Academy of Art in Karlsruhe between 1881 and 1884. In 1890, he joined the group of artists (Grötzinger Malerkolonie) of castle Augustenburg in Grötzingen, near Karlsruhe. From there he travelled regularly through Europe and North Africa.

Beringer, J.A. (1922) Badische Malerei 1770-1920. C.F. Müllersche Hofbuchhandlung, Karlsruhe, Germany.

Staatliche Kunsthalle Karlsruhe (1994), Gustav Kampmann 1859-1917, Zeichnungen aus dem Kupferstichkabinett der Staatlichen Kunsthalle Karlsruhe.

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Chapter Four:	Snow covered woodland with tree-trunks and stumps
Chapter Five:	Study of a young tree
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Conference Workshop Two:	Farm house in Zustorf, 1884
Conference Workshop Three:	Sailing boats close to Hohwardt, 1882
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PREFACE FOR VOLUME III

Oral contributions to international conferences are and will always remain very specific and extremely limited in time. New results can be presented to an experienced audience in a concise way. Usually, there is hardly any time, however, for in-depth discussions.

For this reason, several conference workshops have been incorporated in the scientific programme of the second international conference on fracture mechanics of concrete and concrete structures held at ETH Zürich in July 1995. The major aim of these workshops was to provide a platform for detailed discussions among small groups of experts on controversial views and approaches. The following five topics have been selected by the organizers:

1. Numerical modelling and determination of fracture mechanics parameters.
2. Fracture mechanics and design of concrete structures.
3. Size effects: theoretical concepts, experimental verification, and implications in structural design.
4. Experimental methods.
5. Smeared versus discrete failure analysis with application to pullout problems.

Each topic has been outlined by a small number of invited contributions but most of the time was consecrated to free exchange of ideas and in some cases to confrontation of opposing views. Discussions were guided by a workshop coordinator while a workshop recorder tried to summarize main results and conclusions.

All contributions presented during the five conference workshops are compiled in this volume. In this way, it was possible to publish a state-of-the-art report on the five selected topics. This, hopefully, will help to further develop these areas and to reconcile step by step diverging views.

Every editor of proceedings knows from experience that it is

difficult enough to collect papers before the conference and then have the volumes published in time, but it is even harder to get papers for a post-conference volume. There is no strict deadline any more and most colleagues are already busy to prepare papers for subsequent meetings.

I want to thank all authors for their contributions to this third volume of FRAMCOS 2 Proceedings and, in particular, that they have delivered their contributions inspite of all other commitments. This volume is published a few months later than originally planned. Although fracture mechanics as applied to composite materials such as concrete is a fast moving branch of applied science, most arguments are still valid today. It will be interesting to see during FRAMCOS 3 in Japan which of the still open questions will be solved by then and on which questions further work will still be needed.

Zurich, May 1996

Folker H. Wittmann
Past President of IAFRAMCOS
FRAMCOS-2 Conf. Chairman

PREFACE FOR VOLUMES I AND II

Thirty years ago, fracture mechanics was considered to be a highly interesting academic subject without any relevance for the design, construction, and maintenance of concrete structures. Few and isolated groups worked in this field and they met on the occasion of well established international conferences on fracture mechanics such as ICF. In these big conferences usually one or two sessions were devoted to concrete.

Suddenly, engineers who at that time had no idea what fracture mechanics really implies got fascinated by this approach and the view was spread that civil engineering will experience a real revolution with the introduction of fracture mechanics into structural analysis. These expectations certainly could not and will never be satisfied. But in this situation, RILEM took a lead and set up a first technical committee on fracture mechanics (RILEM TC 50-FMC). The aim originally was to present a comprehensive documentation on the state-of-the-art (Fracture Mechanics of Concrete, ed. F.H. Wittmann, Elsevier (1983)) and to prepare recommendations on a generally accepted test method to determine fracture mechanics parameters. No doubt, practically everybody expected a standardized method on how to determine K_{IC} of concrete when this committee was set up.

It was during the first meeting of the new RILEM technical committee, held in Delft, The Netherlands, when Arne Hillerborg asked for about 15 minutes to present his ideas on fracture mechanics. At that time, nobody really understood the significance of his ideas and long discussions and patience were necessary to convince a majority of committee members, including the chairman, that the fictitious crack model (FCM) is more realistic to describe cracking of concrete-like materials than LEFM. Finally, the elaboration of the RILEM recommendation on the determination of fracture energy of concrete in 1985 was essentially the work of Arne Hillerborg. This publication can be considered as a real milestone (Materials and Structures (1985) 18, 285-296). We are therefore very glad and proud to have Arne Hillerborg as an honorary guest among the participants of FRAMCOS-2.

Once this test method and the underlying concept was published and generally accepted, the number of papers dealing with applications of non-linear fracture mechanics to concrete and concrete structures both numerically and experimentally increased exponentially. It became difficult to follow all these activities. It was Zdenek P. Bazant who took the initiative and in summer 1990 approached a number of colleagues in order to set up IAFRAMCOS, an international association with one major

aim, the organization of a conference on "Fracture Mechanics of Concrete Structures" in regular intervals, typically three years. The first conference was held in Breckenridge, Colorado, USA, in 1992 under the chairmanship of Zdenek P. Bazant. Proceedings of FRAMCOS-1 can be considered as a documentation of the state-of-the-art reached three years ago. At the end of this most successful meeting the general assembly of IAFRAMCOS voted for Zurich to be the place for the second conference, FRAMCOS-2.

We hope to meet again the high standards required for FRAMCOS Proceedings with these volumes. In order to achieve conformity of the presentation we reviewed all submitted contributions carefully and asked some authors for corrections. It was a pleasure to experience a spirit of cooperation with most authors. The few who were not absolutely convinced of the necessity of the proposed corrections will hopefully also be satisfied with the final product.

It is my great pleasure to thank my coworkers for their enormous efforts. Dr. Alejandra M. Alvaredo worked many hours in parallel with the preparation of her own contribution to review and correct papers conscientiously. Mr. Giovanni Martinola and Mr. Bernhard Trunk helped efficiently in this delicate and time consuming operation. Special support by ASMES (Association suisse pour la mécanique des structures) to cover part of the costs for the production of the conference proceedings is gratefully acknowledged. Finally, we could not have finished the editing process in time without the personal engagement of Mrs. Irene Kalt and Mrs. Brigitta de Chapeaurouge.

Zurich, June 1995

Folker H. Wittmann
President IAFRAMCOS
Conference Chairman

FRAMCOS on the Internet

At the Second International Conference on Fracture Mechanics of Concrete Structures (FRAMCOS-2), held at ETH Zurich, Switzerland, in July 1995 a preparatory meeting on Fracture Mechanics on the Internet took place. More than 20 interested FRAMCOS-2 participants discussed the ways of using the Internet for the international communication within the concrete fracture community. The meeting was chaired by V.Slowik. The participants came to the conclusion that a first step might be the efficient exploitation of the World Wide Web (WWW), one of the services provided by the Internet. It was proposed to set up a WWW-server at ETH Zurich, Laboratory for Building Materials, with T.Steiger serving as the webmaster.

In October 1995 the FRAMCOS-WWW-Server started providing its service. The address is:

http://ibwk28.ethz.ch/FRAMCOS/

The intention of this service is to ease the communication between the researchers and to provide some help to people looking for addresses or publications. A fast-loading alphanumeric opening page provides a short table of contents. From there several documents can be opened. In an introduction, general information on the International Association for Fracture Mechanics of Concrete and Concrete Structures (IA-FRAMCOS) is given. The Publications section contains the tables of contents of all past FRAMCOS Conferences and those of seminars and workshops sponsored or co-sponsored by IA-FRAMCOS. A list of names provides the addresses of researchers working on fracture of concrete. As far as http addresses are available the list of names contains links to individual research home pages. All interested researchers are invited to contact the webmaster and have their names, addresses and links to the individual http documents made available by the server.

The number of accesses indicates that people are seriously using the provided service. In February 1996, a daily average of about 70 accesses was monitored. Unfortunately, only a few people did contact the webmaster in order to provide a link to their local http documents. The webmaster, therefore, kindly asks all interested people for the addresses of their individual research home page, if existent.

It is planned to extend the service. If more links to individual home pages are provided a research subject index can be composed. In addition, documents of general interest might be made available for downloading. From the webmaster's point of view, the submission of abstracts as well as the registration for the upcoming FRAMCOS conference can be done via the Internet by using the FRAMCOS-WWW-Server.

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