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Book Review

Fracture Mechanics of Concrete Structures: From theory to applications. Edited by Lennart Elfgren, Chapman and Hall, 1989. ISBN 0 412 30680 8.

Failure of concrete structures always involves growth of fracture surfaces before the maximum load capacity is reached. Yet, despite over 35 years of investigations into the use of fracture mechanics for concrete structures, current design is still not based on fracture concepts. This will change as engineers better understand the role of strain softening, localisation and their link with energy absorption and scale effects. These notions will undoubtedly influence design practice in the near future.

Although published some seven years ago, a large part of this collection of papers remains relevant today. This book accurately represents the work of the RILEM Technical Committee 90-FMA (Fracture Mechanics of Concrete–Applications) at that time, with contributions from 17 of the 18 full members and 7 of the 25 associated members. The 407 page book follows a fairly logical sequence from material to structural levels. The book begins with a brief introduction to the field, followed by a review of fracture mechanics concepts and then discussions on modelling techniques together with a report on size effects and brittleness. These topics account for the first seven chapters. The subsequent ten chapters cover specific structural modes of deformation, the modelling of reinforcement, anchorage in concrete, the use of concrete FM in the analysis of pipes (very brief) and dams (fracture propagation through discrete crack modelling) as well as the application of smeared crack modelling using the NLFE code DIANA in a range of civil engineering problems. The book concludes with a glimpse at the use of ultra-strong cementitious materials and a final review of the role of brittleness in characterising concrete structures together with a suggestion for the direction of future work.

For reference, the chapter headings and corresponding authors are as follows; Introduction (Elfgren), Basic types of failure (Reinhardt), Material models (Elices and Planas), Material properties (Hordijk, van Mier and Reinhardt), Crack concepts and numerical modelling (Hillerborg and Rots), Size effects and brittleness, Other aspects of material modelling (Acker, de Borst, Gylltoft, Modéer and Reinhardt), Size effects and brittleness (di Tommaso), Bending (di Tommaso and Gylltoft), Shear (Reinhardt), Torsion (Elfgren), Punching (Rots), Bond of reinforcement (Rots), Anchorage to concrete (Eligehausen), Pipes (Hillerborg), Dams (Brühwiler, Saouma, Ayari, Boggs and Yaozhong), Joints (Reinhardt), Other applications (van Mier), Fracture mechanics in integrated design of new, ultra-strong materials and structures (Bache), Concluding remarks (Elfgren). Each of the contributions are essentially stand-alone papers (some of which the reviewer recognises from the 1985 Conference on the Fracture Mechanics of Concrete at Laussane, Switzerland). The editor's main additions have been those of ordering of the material, the introductory and concluding remarks, an incomplete list of symbolic notation, a five page index and some useful cross-referencing. Because the entire text has not been re-written as a single document, each of the chapters appear in different typographic styles and some repetition of ideas is evident. This need not be seen as a drawback as alternative presentations and viewpoints on the same material often aid understanding.

Highpoints for this reviewer included the sections by engineers from TNO-IBBC and Delft University on their observations on the performance of smeared crack models in a nonlinear finite element code (although it now appears dated, following the research progress on arc-length solution strategies and regularisation techniques, see for example the 1992 doctoral thesis of L. J. Sluys at Delft University of Technology) and advanced use of discrete crack models in the simulation of the static and dynamic fracturing of concrete dams by researchers in Switzerland and the States. Also worthy of special attention are chapter 4, (which provides a well balanced, enlightened overview of the basic behaviour of cementitious materials under mechanical load) and the forward-looking chapter 18.

At the end of the book the editor points to three areas where further work should be carried out. Here Professor Elfgren reports on the

urgent need for more experimental data on the fracture energy under combined tension and shear, for the relative merits of different material models to be discussed and for greater practical application of fracture mechanics to reinforced concrete structures. Over the past seven years, there has been some progress in the first area, there has also been a continued development of material models (although no single model has emerged as the most representative) but there remains a dearth of applications. Despite the noticeable increases in the processing power of digital computers, a number of significant computational problems persist (primarily related to the inability to realistically, stably and efficiently model three-dimensional fracture opening, growth and closure in reinforced concrete). Although we are getting close, we still do not have access to reliable general purpose analytical tools which can accurately simulate the complete deformation behaviour of real reinforced concrete structures under mechanical load.

Finally the reviewer notes that the publication of this collection took place the same year as Part I of the State-of-the-Art Report by ACI Committee 446 (Fracture Mechanics of Concrete) was approved for release. This latter document offers a unified presentation, rather than a compilation as found in the book reviewed here. Any reader with an interest in this field would do well to examine both documents as well as the more recent texts (including for example, Chapters 2, 3 and 7 in the 1993 ASCE/ACI 447 report on Finite Element Modelling of Reinforced Concrete Structures II, Isenberg, J. (Ed.)).

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