PREFACE

The purpose of this text is to present the nonlinear finite element analysis and constitutive laws for reinforced concrete developed by our research group in the University of Tokyo during past one decade.

In 1974, I could get the opportunity to touch the finite element approach to the engineering materials and structures through the cooperative project on composite material organized by Prof. Masatane Kokubu and supervised by Prof. Yoshi-aki Yamada. The finite element approach attracted me so much as a generalized analysis technique and a unified theory with wide applicability to reinforced concrete behaviors. I started the research to aim at developing the predictive method for reinforced concrete mechanics. To establish this methodology, I regarded the constitutive laws for reinforced concrete as an essential and indispensable origination for structural behaviors of interest, and has been focusing my effort on the modeling of uncracked and cracked concrete, bond between concrete and reinforcement and steel in concrete subjected not only to monotonic but to the reversed cyclic loading.

As an accomplishment of our group, two dimensional finite element program named "WCOMR" [Reinforced Concrete Model for Walls subjected to Reversed Cycylic Load], which is applicable to two dimensional structures subjected to in-plane loading, was released. The detail of this program and development procedure are presented in this text. The most important feature of "WCOMR" is the enhanced constitutive material models installed. It is clearly understood and demonstrated that the accuracy and reliability of nonlinear analysis is governed by the level of constitutive modeling, which is the beginning from which any kind of structural nonlinearity of reinforced concrete is predicted. In the development process, much attention has been paid to the verification of models in the material, member and structural levels. This book also serves possibly to demonstrate our strategy and research methodology on nonlinear structural reinforced concrete.

As a new attempt, the bilingual text with colored figures is edited here with due consideration of convenience for readers. Japanese and English bilingual edition is devoted to both domestic and international staffs, students and engineers. Multi-colored figures are expected to aid readers recognizing truly the close coincidence of analysis with experiments especially in reversed cyclic load. A further feature of the book is that each chapter is arranged so that the readers can proceed from the first chapter in general of analytical method and strategy, and stop reading at any chapter. The interested readers can carry on with further chapters in details of constitutive modeling. Therefore, there is not any citation and reference of equations in the text. Mathematical expression and notations are referred in relevant figures. This book and the program "WCOMR" have potential usage in teaching as well as research environments.

Since the progress has been achieved with continued efforts by a lot of students and staffs and by the stimulation performed through relation with external associations, here, I look back upon the past progress and presentation of this approach.

In 1979, as the initiation and the first opportunity of presenting research works arising from our organization, Dr. T. Nomura reported the finite element analysis of reinforced concrete beams subjected to shear in IABSE colloquium, Copenhagen. At that time when we were just at the very beginning, we did not clearly understand what is the essential, and much information from this colloquium was brought to us. The shear failure of RC beams was recognized as one of the very tough problems associated with the crack propagation and bond. This problem, at which the finite element approach is not good, has never been solved.

As an extension of research in Copenhagen, the analysis oriented to the capacity of deep beams was presented by Drs. J. Niwa and K. Maekawa in IABSE colloquium, Delft, 1981. Through this occasion organized by Delft University of Technology group, the topics to be discussed, such as propagation of discrete crack, multi-axial concrete model and stability of solution related to strain-softening, were clarified. Here, we could know the DIANA project and research on constitutive model and analysis supervised by Prof. J. Blaauwendraad in Delft. They were very impressive and advisable for us.

In the above colloquium, Prof. M. P. Collins in University of Toronto announced the competition of prediction on RC panel behaviors. This was to invite predictions for the behavior of selected RC panels from worldwide institutes, and to compare them with experimental data which was conducted by University of Toronto but of which the applicants were not informed in advance. Based on the elasto-plastic and fracture model for uncracked and cracked concrete, which was first presented by my co-author in UTAM symposium organized by Prof. Z. P. Bazant of Northwestern University in 1983, we applied our analytical results to this exciting attempt. Although our prediction was ranked as the second best, we failed to predict the behaviors of one panel among four. The comparison of the analytical with the experimental results accelerated our research on smeared crack model for reinforced concrete. This competition in 1982 resulted in a stepping stone for us to focus our main efforts on the enhancement of constitutive laws. The research project was strongly oriented.

Meanwhile, the US-Japan Joint seminar on finite element analysis of reinforced concrete was held in 1985 sponsored by NSF and JSPS. This symposium organized by Prof. C. Meyer in Columbia University and myself was a timely opportunity to exchange knowledge among researchers and to steer our way to the generalized constitutive law for reinforced concrete. This occasion gave rise to the cooperation between ASCE and JCI committees. Here, the application of FEM to the practical design was deemed as the topic to be guided in future. The product of the meeting was edited in a volume published by ASCE. The second joint seminar is scheduled in 1991.

After US-Japan seminar, IABSE colloquium on finite element of reinforced concrete was again organized by Prof. J. Blaauwendraad in Delft University of Technology. I and my co-workers firstly presented the cyclic constitutive models and analysis of in-plane structures. The main part of this text is considered to be established at that time. Further development, which is not basically compiled in this book but scheduled to be published in the future edition, was presented in 1990 at the international conference held in Zel-am-See by Prof. H. Mang in Technical University, Vienna, who was also a contributor of the US-Japan seminar.

In this progress, I could get several opportunities to offer lectures in some institutes on the topic related to this book. I sincerely thank Prof. N. Hawkins in University of Washington (1989), Prof. J.E. Breen and Prof. J.O. Jirsa in University of Texas at Austin (1989), and Prof. W. Kanok-Nukurchai in Asian Institute of Technology (1990) for giving me the valuable time. I am indebted to many people for their direct and indirect assistance in going on this research project entitled. I sincerely express my gratitude to my co-author, Dr. K. Maekawa and the Tokyo graduates who have been involved in this long-term research. This preface would not be complete without a record of my gratitude to Professor Emeritus Kokubu Masatane and the late Professor P. Furguson, from whom I could acquire the way of research.

January 1991 Hajime Okamura