Preface

This book presents the constitutive modeling of reinforced concrete and nonlinear structural mechanics that should be taken into account in the practical design of reinforced concrete structures. Cracking is one of the major sources of nonlinearity. Accordingly, space-averaging procedures over finite domains with multi-directional cracking are given for both two- and three-dimensional fields. Regarding applicability, all mechanical modeling in this book is verified not only by material or element-based experiments but also by reinforced-concrete structural behavior that has significant implications for structural design. This book provides modeling of reinforced concrete for practical use, especially for seismic performance assessment and structural safety checking under static and dynamic design loads.

Performance-based design may be regarded as a scheme to explicate targeted functions and levels of performance to clients and users in a transparent manner. Currently, it is occupying the central position as a design procedure for the next generation of buildings and infrastructure. In 1995, the Hyogo-ken Nanbu earthquake struck the city of Kobe. More than 6000 lives were lost and approximately 13% of reinforced-concrete bridges were seriously damaged. Since this tragedy, transparency of design has been strongly requested by both taxpayers and clients, and structural engineers have been required to take responsibility for the realized quality and performance actualized in the real world of their designs. In this context, the stimulation of structural response under combinations of mechanical loadings and varying environmental conditions is of great value in examining design performance. Here we are mainly concerned with discussing nonlinear finite element analysis with consistent constitutive modeling as an engineering means of assessing performance in terms of safety and functionality.

Our first book (1991) covered constitutive models of reinforced concrete, principally for in-plane members under reversed cyclic loads. Subsequently, applicability has been extended by theoretical advances, and the coverage of structural types and loading patterns and magnitudes has been widened in engineering terms. In the past decade, some seismic design codes have been issued for safety assurance and cost-saving in the construction of energy facilities, based on two- and three-dimensional nonlinear finite element analysis. Given these developments and accumulated engineering experience, this new book deals with all kinds of structural members, such as beams, columns, slabs, walls, three-dimensional shells, footings, piles, and soil – reinforced concrete systems, and a wide variety of loadings, such as monotonic, reversed cyclic, static and dynamic, coupled flexure-shear and torsion, and proportional and non-proportional loading paths.

An important feature of the modeling is the consistency of its application to any type of structure and of loading through the nonlinear dynamic finite element coding in the programs *WCOMD* for two dimension and *COM3* for three dimensions. These programs have been released and their β-versions with limited functions are downloadable from www.forum8.co.jp. Readers may find these programs increase their understanding, and they may also be useful for educational purposes.

This book is the result of a long-term project on the structural mechanics of concrete. In the first period, from 1980 to 1990, the general direction of research was established after many trials and errors, and the in-plane multi-directional cracking model for simple nonlinear dynamics was completed. The second period, from 1990 to 1995, was a time of consolidation and improvement. The direct integration of nonlinear governing equations in time domain was computationally enhanced to include opening and closure of multi-directional cracks and highly plastic evolution of reinforcement. A major attempt was made to apply nonlinear analysis directly to practical design codes. In the third period, from the Hyogo-ken Nanbu earthquake in 1995 to the present, nonlinear finite element analyses were widely conducted to investigate the causes of failure and examine the seismic safety performance in service of many existing structures. It could be said that using nonlinear simulation to address these engineering needs has been a strong driving force behind current progress. Recently, three-dimensional nonlinear finite element analysis of complete soil – reinforced concrete structures has been established as one of the major tools in the practical design specification of energy facilities. Now is therefore a good time to draw together the knowledge and unify the technology of the nonlinear mechanics of reinforced concrete.

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(cyclic full three-dimensional analysis and high-strength materials). The combined knowledge and insight of many engineers has been the key factor in developing this book.

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