Preface

Computational mechanics have made a strong impact on classical continuum mechanics, which include engineering mechanics and structure mechanics. Earthquake engineering has achieved significant progress with the aid of computational mechanics. This book intends to cover some new aspects of earthquake engineering that are based on computational mechanics, i.e. computational earthquake engineering.

The book consists of four parts. The first part covers preliminaries and provides the basics of continuum mechanics, the finite element method and stochastic modeling. Only the key points of these subjects are briefly covered in this part. The first subject, however, is explained by separating physical principles and mathematical treatment to show that the basic structure of solid mechanics is as simple as a spring problem. The formulation and algorithms of the finite element method are included in the second subject; knowledge of existing numerical computation techniques is inevitably required to improve existing numerical analysis methods and to develop new ones. The third subject, stochastic modeling, is not necessarily known in earthquake engineering as it exists today, however, it is essential for later developments in the book and so is included in the first part.

The second and third parts make up the main content of this book. These two parts cover numerical analysis of strong ground motion and faulting respectively. The basics of the wave equation and failure analysis are briefly covered in the beginning of the second part. A stochastic model is constructed for underground structures, and a theory for wave propagation and fault rupture processes in this stochastic setting is explained. The theory leads to two analysis methods, namely, an analysis which provides bounds for the mean of the stochastic model response, and an analysis which fully calculates stochastically varying response of the stochastic model. Multiscale analyses based on singular perturbation expansion and linear/non-linear failure analysis of the stochastic underground model are also provided for large-scale computation of strong ground motion and for the formation of faults on the ground surface. Illustrative numerical examples involving actual strong ground motion and faulting are presented. The theory and analyses explained in these parts of the book are not standard subjects of conventional earthquake engineering. However, they do emerge in various fields of engineering and science which are closely related to computational mechanics and are applicable to various problems of earthquake engineering. With the aid of the analysis methods, high spatial and temporal resolution can be achieved in numerical simulations of strong ground motion for a given scenario of an earthquake. That is, the wave propagation processes from a fault to a target site are computable. The numerical analysis of the rupture processes in soil layers of uncertain composition leads to estimates of the probability that a surface earthquake fault is formed on the ground surface. The hazard of faulting is thus discussed based on quantitative information. For numerical analysis, the finite element method is mainly used to solve earthquake wave propagation problems and fault formation problems, although the boundary element method is used for the latter as well.

The last part of the book presents three advanced topics in computational earthquake engineering. The application of computer science and technology is not limited to numerical computation, and the following three topics are examples of such application. The topics are: seamless modeling and analysis of all phases of earthquake hazard and disaster by combining numerical analysis methods with Geographical Information Systems; the visualisation of earthquake disaster simulation using various numerical methods integrated into one system with the aid of artificial intelligence and an efficient object-oriented description of earthquake resistant design codes to broaden and disseminate knowledge of seismic structure response.

It should be emphasised that computational earthquake engineering is a rapidly developing field. For earthquake engineering, interaction with computational science and technology is essential since earthquakes are rare events and therefore simulation is a rational way to study earthquake hazard and disaster.

In closing this preface, the author expresses the sincerest appreciation to former graduate students of the University of Tokyo who have worked with him. They are Navaratnam Vaikunthan, H. M. Sunil Munashinge, Maciej Szymon Anders, Tsuyoshi Ichimura, and Hidenori Nakagawa. Without their enormous efforts, this book could not have been realised. The author is also grateful for comments, discussions and suggestions made by his colleagues

in Earthquake Research Institute and Department of Civil Engineering, the University of Tokyo, namely, Kenji Oguni, Hiromichi Higashihara, Kazuo Konagai, Yozo Fujino, Yoshio Fukao, Takehiro Koyaguchi, and Yasuko Takei. Finally, he is thankful for the support made by his family during the writing of this book.

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July 2005