

THE  

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CIVIL  
ENGINEERING  

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HANDBOOK  

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**SECOND EDITION**

# New Directions in Civil Engineering

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*Hawaii University*

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EDITED BY  
W.F. CHEN  
J.Y. RICHARD LIEW



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# Preface

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The second edition of the *Civil Engineering Handbook* has been revised and updated to provide a comprehensive reference work and resource book covering the broad spectrum of civil engineering. This book has been written with the practicing civil engineer in mind. The ideal reader will be a BS- or MSc-level engineer with a need for a single reference source to use to keep abreast of new techniques and practices as well as to review standard practices.

The *Handbook* stresses professional applications, placing great emphasis on ready-to-use materials. It contains many formulas and tables that give immediate solutions to common questions and problems arising from practical work. It also contains a brief description of the essential elements of each subject, thus enabling the reader to understand the fundamental background of these results and to think beyond them. Traditional as well as new and innovative practices are covered.

As a result of rapid advances in computer technology and information technology, a revolution has occurred in civil engineering research and practice. A new aspect, *information technology and computing*, has been added to the theoretical and experimental aspects of the field to form the basis of civil engineering. Thorough coverage of computational and design methods is essential in a knowledge-based economy. Thus, computational aspects of civil engineering form the main focus of several chapters. The *Civil Engineering Handbook* is a comprehensive handbook, featuring a modern CAD/CAE approach in advancing civil engineers in the 21<sup>st</sup> century. The *Handbook* is organized into eight sections, covering the traditional areas of civil engineering: construction engineering, materials engineering, environmental engineering, structural engineering, geotechnical engineering, surveying engineering, hydraulic engineering, and transportation engineering.

The subdivision of each section into several chapters is made by the associate editors and is somewhat arbitrary, as the many subjects of the individual chapters are cross-linked in many ways and cannot be arranged in a definite sequence. To this end, in addition to the complete table of contents presented at the front of the book, an individual table of contents precedes each of the eight sections and gives a general outline of the scope of the subject area covered. Finally, each chapter begins with its own table of contents. The reader should look over these tables of contents to become familiar with the structure, organization, and content of the book. In this way, the book can also be used as a survey of the field of civil engineering, by the student or civil engineer, to find the topics that he or she wants to examine in depth. It can be used as an introduction to or a survey of a particular subject in the field, and the references at the end of each chapter can be consulted for more detailed studies.

The chapters of the *Handbook* have been written by many authors, all experts in their fields, and the eight sections have been carefully edited and integrated by the various associate editors in the School of Civil Engineering at Purdue University and the Department of Civil Engineering at the National University of Singapore. This *Handbook* is a testimonial to the dedication of the associate editors, the publisher, and the editorial associates. I wish to thank all of the authors for their contributions and the

reviewers for their constructive comments. I also wish to acknowledge at CRC Press, Helena Redshaw, Elizabeth Spangenberg, Susan Fox, and Cindy Carelli for their professional support in revising this handbook.

**W. F. Chen**  
**J. Y. Richard Liew**  
Editors-in-Chief

# Editors-in-Chief

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**W. F. Chen** is presently Dean of the College of Engineering at the University of Hawaii. He was a George E. Goodwin Distinguished Professor of Civil Engineering and Head of the Department of Structural Engineering at Purdue University from 1976 to 1999.

He received his B.S. in civil engineering from the National Cheng-Kung University, Taiwan, in 1959, M.S. in structural engineering from Lehigh University, PA, in 1963, and Ph.D. in solid mechanics from Brown University, RI, in 1966. He received the Distinguished Alumnus Award from the National Cheng-Kung University in 1988 and the Distinguished Engineering Alumnus Medal from Brown University in 1999.

Dr. Chen's research interests cover several areas, including constitutive modeling of engineering materials, soil and concrete plasticity, structural connections, and structural stability. He is the recipient of several national engineering awards, including the Raymond Reese Research Prize and the Shortridge Hardesty Award, both from the

American Society of Civil Engineers, and the T. R. Higgins Lectureship Award from the American Institute of Steel Construction. In 1995, he was elected to the U.S. National Academy of Engineering. In 1997, he was awarded Honorary Membership by the American Society of Civil Engineers. In 1998, he was elected to the Academia Sinica (National Academy of Science) in Taiwan.

A widely respected author, Dr. Chen authored and coauthored more than 20 engineering books and 500 technical papers. His books include several classical works such as *Limit Analysis and Soil Plasticity* (Elsevier, 1975), the two-volume *Theory of Beam-Columns* (McGraw-Hill, 1976–77), *Plasticity in Reinforced Concrete* (McGraw-Hill, 1982), and the two-volume *Constitutive Equations for Engineering Materials* (Elsevier, 1994). He currently serves on the editorial boards of more than 10 technical journals. He has been listed in more than 20 *Who's Who* publications.

Dr. Chen is the editor-in-chief for the popular 1995 *Civil Engineering Handbook*, the 1997 *Handbook of Structural Engineering*, and the 1999 *Bridge Engineering Handbook*. He currently serves as the consulting editor for McGraw-Hill's *Encyclopedia of Science and Technology*.

He has been a longtime member of the Executive Committee of the Structural Stability Research Council and the Specification Committee of the American Institute of Steel Construction. He has been a consultant for Exxon Production Research on offshore structures, for Skidmore, Owings, and Merrill in Chicago on tall steel buildings, and for the World Bank on the Chinese University Development Projects, among many others.

Dr. Chen has taught at Lehigh University, Purdue University, and the University of Hawaii.





**J. Y. Richard Liew** is presently associate professor with the Department of Civil Engineering at the National University of Singapore. He received his B.Eng. and M.Eng in Civil Engineering from the National University of Singapore, in 1986 and 1988, respectively, and Ph.D. in Structural Engineering from Purdue University, West Lafayette, IN, in 1992.

Dr Liew published more than 100 papers covering topics such as steel design, frame stability, and steel-concrete composite structures. He is actively involved in research on innovative lightweight structures covering wide aspects of structural mechanics problems, including joint effects, composite actions between various materials, cable tensioning problems, and high temperature and high strain rate effects. He also worked on product development using fiber-reinforced polymer materials for structural applications. Dr. Liew authored and coauthored two books and more than ten engineering book chapters. He served on two editorial boards of technical journals related to steel and composite structures.

He is a member of the American Society of Civil Engineers and the Institute of Structural Engineers in the U.K. He is a Chartered Engineer of the U.K. He is currently (2002) the president of the Singapore Structural Steel Society. He has been serving as a specialist advisor to several national organizations on steel specifications and projects, to consultants and steel fabricators for special projects related to large span steel structures and high-rise steel buildings, among others.

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Elementary Algebra and Geometry

Determinants, Matrices, and Linear Systems of Equations

Trigonometry

Analytic Geometry

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