SECOND EDITION

Fundamentals of Structural Analysis

Kenneth M. Leet Chia-Ming Uang

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Second Edition

Kenneth M. Leet
Professor Emeritus, Northeastern University

Chia-Ming Uang
Professor, University of California, San Diego

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This book is dedicated to our wives and children and the many teachers and professional engineers who contributed to our knowledge of structural analysis and behavior.

ABOUT THE AUTHORS

Kenneth Leet received his Ph.D. in structural engineering from the Massachusetts Institute of Technology. As a professor of civil engineering at Northeastern University, he taught graduate and undergraduate courses in reinforced concrete design, structural analysis, foundations, plates and shells, and capstone courses on comprehensive engineering projects for over thirty years. Professor Leet was given an Excellence in Teaching award at Northeastern University in 1992. He was also a faculty member for ten years at Drexel University in Philadelphia.

In addition to being the author of the first edition of this book on structural analysis, originally published by Macmillan in 1988, he is the author of *Fundamentals of Reinforced Concrete,* published by McGraw-Hill in 1982 and now in its third edition.

Before teaching, he was employed by the Corps of Army Engineers as a construction management engineer, by Catalytic Construction Company as a field engineer, and by several structural engineering firms as a structural designer. He has also served as a structural consultant to a number of government agencies and private firms, including the U.S. Department of Transportation, Procter & Gamble, Teledyne Engineering Services, and the City of Philadelphia and Boston Bridge Departments.

As a member of the American Arbitration Association, the American Concrete Institute, the ASCE, and the Boston Society of Civil Engineers, Professor Leet actively participated in professional societies for many years.

Chia-Ming Uang is a professor of structural engineering at the University of California, San Diego (UCSD). He received a B.S. degree in civil engineering from National Taiwan University and M.S. and Ph.D. degrees in civil engineering from the University of California, Berkeley. His research areas include seismic analysis and design of steel, composite, and timber structures.

Professor Uang also coauthored the text *Ductile Design of Steel Structures* for McGraw-Hill. He received the UCSD Academic Senate Distinguished Teaching Award in 2004. He is also the recipient of the ASCE Raymond C. Reese Research Prize in 2001 and the Moisseiff Award in 2004.

PREFACE

This text introduces engineering and architectural students to the basic techniques required for analyzing the majority of structures and the elements of which most structures are composed, including beams, frames, arches, trusses, and cables. Although the authors assume that readers have completed basic courses in statics and strength of materials, we briefly review the basic techniques from these courses the first time we mention them. To clarify the discussion, we use many carefully chosen examples to illustrate the various analytic techniques introduced, and whenever possible, we select examples confronting engineers in real-life professional practice.

Features of This Text

1. **Expanded treatment of loads.** Chapter 2 is devoted to a comprehensive discussion of loads that includes dead and live loads, tributary areas, and earthquake and wind forces. New to this edition are updated wind and earthquake specifications that conform to the latest edition of the ASCE Standard. We have simplified the more complex provisions of the most recent national building code (ANSI/ASCE), intended for professional engineers, to provide readers with a basic understanding of how multistory buildings, bridges, and other structures respond to earthquake and wind loads in various areas of the United States. This chapter can be used as a helpful reference for courses that combine analysis and design as well as capstone courses that cover comprehensive design projects.
2. **New homework problems.** We have increased the number of new homework problems substantially; about 60 percent of the problems are revised or are new (in both metric and U.S. Customary System units), and many are typical of analysis problems encountered in practice. The many choices enable the instructor to select problems suited for a particular class or for a particular emphasis.
3. **New computer problems and applications.** Computer problems, new to this edition, provide readers with a deeper understanding of the structural behavior of trusses, frames, arches, and other structural systems. These simple, carefully tailored problems illustrate significant aspects of structural behavior that, in the past, experienced designers needed many years of practice to under-

stand and analyze correctly. The computer problems are identified with a computer screen icon and begin in Chapter 4 of the text. The new computer problems can be solved using the Educational Version of the commercial software RISA-2D that is available to users on the text's new Online Learning Center. However, any software that produces deflected shapes as well as shear, moment, and axial load diagrams can be used to solve the problems. An overview on the use of the RISA-2D software and an author-written tutorial are also available at the Online Learning Center.

4. **Expanded discussion of the general stiffness method.** Chapter 16, on the general stiffness method, provides a clear transition from classical methods of analysis to those using matrix formulations for computer analysis, as discussed in Chapters 17 and 18.
5. **Realistic, fully drawn illustrations.** The illustrations in the text provide a realistic picture of actual structural elements and a clear understanding of how the designer models joints and boundary conditions. Photographs complement the text to illustrate examples of building and bridge failures.
6. **New Online Learning Center.** This text offers a new Web-based learning center available to users at www.mhhe.com/leet2e. The site offers an array of tools, including lecture slides, an image bank of the text's art, helpful Web links, and the RISA-2D educational software.

Contents and Sequence of Chapters

We present the topics in this book in a carefully planned sequence to facilitate the student's study of analysis. In addition, we tailor the explanations to the level of students at an early stage in their engineering education. These explanations are based on the authors' many years of experience teaching analysis.

Chapter 1 provides a historical overview of structural engineering (from earliest post and lintel structures to today's high-rises and cable bridges) and a brief explanation of the interrelationship between analysis and design. We also describe the essential characteristics of basic structures, detailing both their advantages and their disadvantages.

Chapter 2 on loads is described above in *Features of This Text*.

Chapters 3, 4, and 5 cover the basic techniques required to determine bar forces in trusses, and shear and moment in beams and frames. The methods developed in these chapters are used to solve almost every problem in the remainder of the text.

Chapters 6 and 7 interrelate the behavior of arches and cables and cover their special characteristics (of acting largely in direct stress and using materials efficiently).

Chapter 8 covers methods for positioning live load on determinate structures to maximize the internal force at a specific section of a beam or frame or in the bars of a truss.

Chapters 9 and 10 provide methods used to compute the deflections of structures to verify that a structure is not excessively flexible and to analyze indeterminate structures by the method of consistent deformations.

Chapters 11, 12, and 13 introduce several classical methods for analyzing indeterminate structures. Although most complex indeterminate structures are now analyzed by computer, certain traditional methods (e.g., moment distribution) are useful to estimate the forces in highly indeterminate beams and frames to verify the computer solution.

Chapter 14 extends the methods used in Chapter 8 to analyze indeterminate structures. Engineers use the techniques in both chapters to design bridges or other structures subject to moving loads or to live loads whose position on the structure can change.

Chapter 15 gives approximate methods of analysis, used to estimate the value of forces at selected points in highly indeterminate structures. With approximate methods, designers can verify the accuracy of computer studies or check the results of more traditional, lengthy hand analyses described in earlier chapters.

Chapters 16, 17, and 18 introduce matrix methods of analysis. Chapter 16 extends the general stiffness method to a variety of simple structures. The matrix formulation of the stiffness method is applied to the analysis of trusses (Chap. 17) and to the analysis of beams and frames (Chap. 18).

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We would like to remember my late editor David E. Johnstone of Macmillan and acknowledge his invaluable help with the first edition of this book.

We would like to thank Richard Scranton, Saul Namyet, Robert Taylor, Marilyn Scheffler, and Anne Gilbert for their help with the first edition of this book, and Dennis Bernal who wrote Chapter 18, all then of Northeastern University.

We also wish to thank Bruce R. Bates of RISA Technologies for providing a student version of the advanced RISA-2D computer program with its many options for presenting results.

Also the many hours of editing and support provided by my wife, Judith Leet, are deeply appreciated.

For their assistance with the first edition, the authors want to thank Amy Hill, Gloria Schiesl, Eric Munson, Suzanne Jeans, and Patti Scott of McGraw-Hill and Jeff Lachina.

For their assistance with the second edition, the authors thank Amanda Green, Suzanne Jeans, and Jane Mohr of McGraw-Hill; Jeff Lachina of Lachina Publishing Services; and Patti Scott, who edited the second edition.

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Kenneth Leet
Emeritus Professor
Northeastern University

Chia-Ming Uang
Professor
University of California,
San Diego

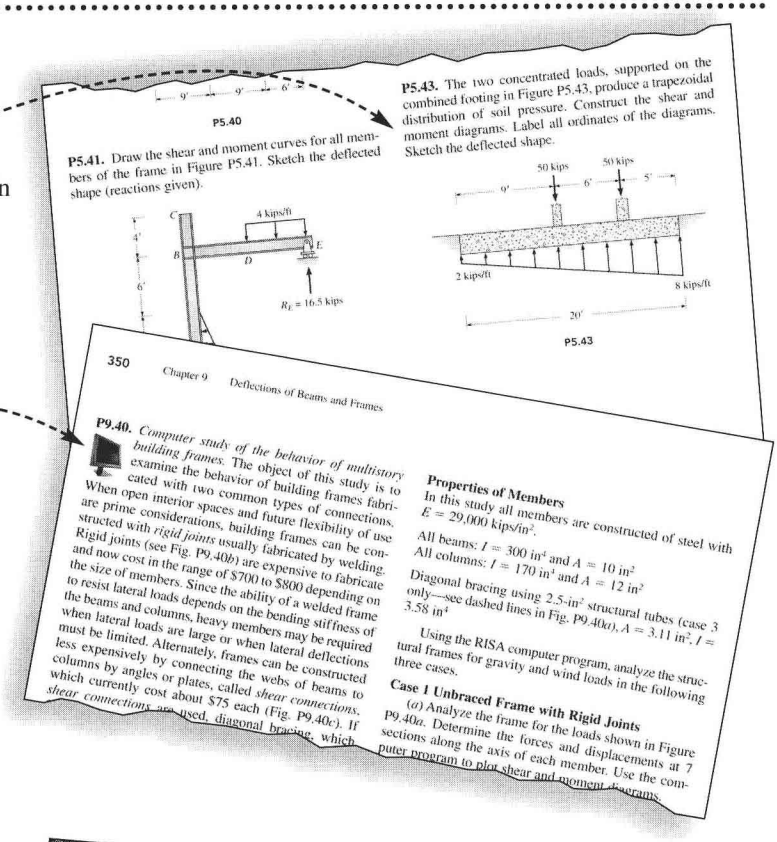
GUIDED TOUR

Approach

Leet and Uang combine a mix of classical methods and computer analysis.

Approximately 60% of the homework problems in this text are new or revised.

Computer icons throughout the text point to homework problems that can be analyzed using a computer.



P5.40

P5.41. Draw the shear and moment curves for all members of the frame in Figure P5.41. Sketch the deflected shape (reactions given).

P5.43. The two concentrated loads, supported on the combined footing in Figure P5.43, produce a trapezoidal distribution of soil pressure. Construct the shear and moment diagrams. Label all ordinates of the diagrams. Sketch the deflected shape.

P5.43

P9.40. *Computer study of the behavior of multistory building frames.* The object of this study is to examine the behavior of building frames fabricated with two common types of connections. When open interior spaces and future flexibility of use are prime considerations, building frames can be constructed with *rigid joints* usually fabricated by welding. Rigid joints (see Fig. P9.40*b*) are expensive to fabricate and now cost in the range of $700 to $800 depending on the size of members. Since the ability of a welded frame to resist lateral loads depends on the bending stiffness of the beams and columns, heavy members may be required when lateral loads are large or when lateral deflections must be limited. Alternately, frames can be constructed less expensively by connecting the webs of beams to columns by angles or plates, called *shear connections*, which currently cost about $75 each (Fig. P9.40*c*). If *shear connections* are used, diagonal bracing, which

Properties of Members

In this study all members are constructed of steel with $E = 29{,}000$ kips/in^2.

All beams: $I = 300$ in^4 and $A = 10$ in^2

All columns: $I = 170$ in^4 and $A = 12$ in^2

Diagonal bracing using 2.5-in^2 structural tubes (case 3 only—see dashed lines in Fig. P9.40*a*), $A = 3.11$ in^2, $I = 3.58$ in^4

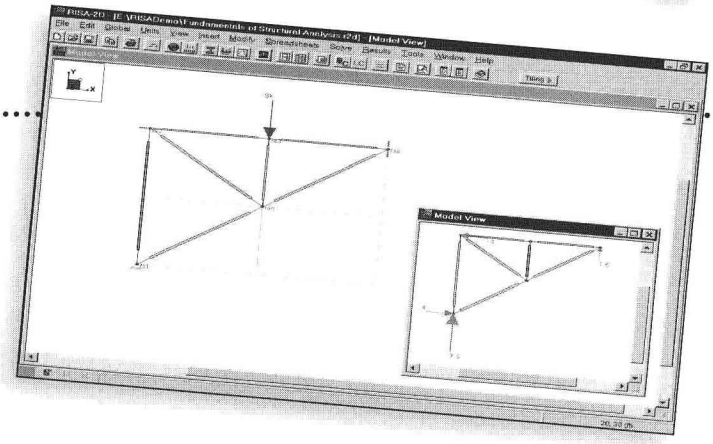
Using the RISA computer program, analyze the structural frames for gravity and wind loads in the following three cases.

Case 1 Unbraced Frame with Rigid Joints

(*a*) Analyze the frame for the loads shown in Figure P9.40*a*. Determine the forces and displacements at 7 sections along the axis of each member. Use the computer program to plot shear and moment diagrams.

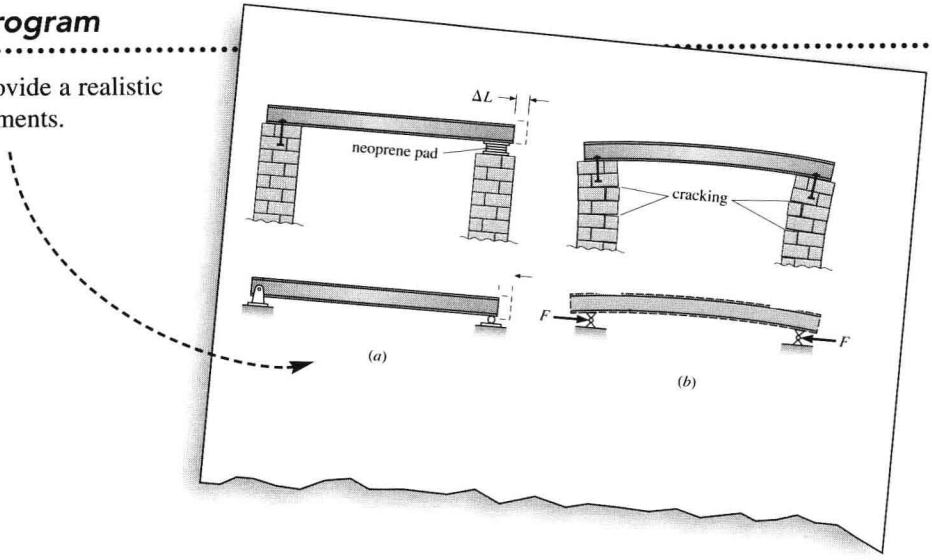
RISA-2D Educational Software

Students may download a free academic version of RISA-2D and an author-written, tutorial with the purchase of a new text.



Highly Realistic Art Program

The illustrations in the text provide a realistic picture of actual structural elements.

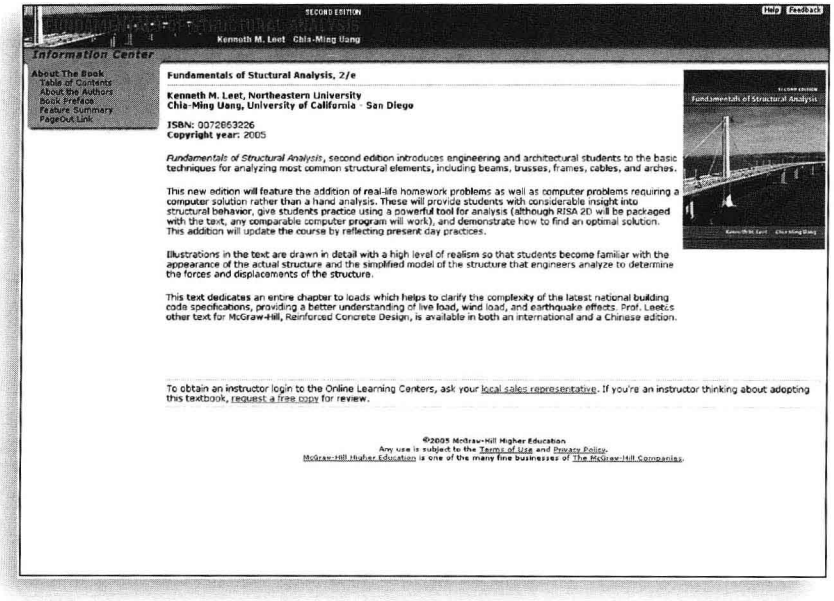


Supplements

The text offers a new Web-based, Online Learning Center at www.mhhe.com/leet2e. The site offers an array of tools such as helpful Web links, the educational version of the RISA-2D software, an author-written tutorial, an instructor's solutions manual, and more!

The text's images are available to instructors in PowerPoint form for instructor classroom use.

Lecture slides are available in PowerPoint form for instructor classroom use. The slides are helpful for review.



The end of chapter summaries allow students to review the most important concepts of each chapter.

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