DESIGN OF REINFORCED CONCRETE

NINTH EDITION

JACK C. McCORMAC • RUSSELL H. BROWN

Design of Reinforced Concrete

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ACI 318-11 Code Edition

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Preface

Audience

This textbook presents an introduction to reinforced concrete design. We authors hope the material is written in such a manner as to interest students in the subject and to encourage them to continue its study in the years to come. The text was prepared with an introductory three-credit course in mind, but sufficient material is included for an additional three-credit course.

New to This Edition

Updated Code

With the ninth edition of this text, the contents have been updated to conform to the *2011 Building Code of the American Concrete Institute* (ACI 318-11). Changes to this edition of the code include:

- Factored load combinations are now based on ASCE/SEI 7-10, which now treats wind as a strength level load.
- Minor revisions to development length to headed bars.
- Addition of minimum reinforcement provisions to deep beams.
- Introduction of Grade 80 deformed bars in accordance with ASTM 615 and ASTM 706.
- Zinc and epoxy dual-coated reinforcing bars are now permitted in accordance with ASTM A1055.

New Chapter on Concrete Masonry

A new chapter on strength design of reinforced concrete masonry has been added to replace the previous Chapter 20 on formwork. Surveys revealed that the forms chapter was not being used and that a chapter on masonry would be more valuable. Because strength design of reinforced concrete masonry is so similar to that of reinforced concrete, the authors felt that this would be a logical extension to the application of the theories developed earlier in the text. The design of masonry lintels, walls loaded out-of-plane, and shear walls are included. The subject of this chapter could easily occupy an entire textbook, so this chapter is limited in scope to only the basics. An example of the design of each type of masonry element is also included to show the student some typical applications.

Units Added to Example Problems

The example problems now have units associated with the input values. This will assist the student in determining the source of each input value as well as help in the use of dimensional analysis in determining the correct answers and the units of the answers. Often the student can catch errors in calculations simply by checking the dimensions of the calculated answer against what the units are known to be.

Organization

The text is written in the order that the authors feel would follow the normal sequence of presentation for an introductory course in reinforced concrete design. In this way, it is hoped that skipping back and forth from chapter to chapter will be minimized. The material on columns is included in three chapters (Chapters 9, 10, and 11). Some instructors do not have time to cover the material on slender columns, so it was put in a separate chapter (Chapter 11). The remaining material on columns was separated into two chapters in order to emphasize the difference between columns that are primarily axially loaded (Chapter 9) and those with significant bending moment combined with axial load (Chapter 10). The material formerly in Chapter 21, "Seismic Design of Concrete Structures," has been updated and moved to a new appendix (Appendix D).

Instructor and Student Resources

The website for the book is located at www.wiley.com/college/mccormac and contains the following resources.

For Instructors

Solutions Manual A password-protected Solutions Manual, which contains complete solutions for all homework problems in the text, is available for download. Most are handwritten, but some are carried out using spreadsheets or Mathcad.

Figures in PPT Format Also available are the figures from the text in PowerPoint format, for easy creation of lecture slides.

Lecture Presentation Slides in PPT Format Presentation slides developed by Dr. Terry Weigel of the University of Louisville are available for instructors who prefer to use PowerPoint for their lectures. The PowerPoint files are posted rather than files in PDF format to permit the instructor to modify them as appropriate for his or her class.

Sample Exams Examples of sample exams are included for most topics in the text. Problems in the back of each chapter are also suitable for exam questions.

Course Syllabus A course syllabus along with a typical daily schedule are included in editable format.

Visit the Instructor Companion Site portion of the book website at www.wiley.com/college/mccormac to register for a password. These resources are available for instructors who have adopted the book for their course. The website may be updated periodically with additional material.

For Students and Instructors

Excel Spreadsheets Excel spreadsheets were created to provide the student and the instructor with tools to analyze and design reinforced concrete elements quickly to compare alternative solutions. Spreadsheets are provided for most chapters of the text, and their use is self-explanatory. Many of the cells contain comments to assist the new user. The spreadsheets can be modified by the student or instructor to suit their more specific needs. In most cases, calculations contained within the spreadsheets mirror those shown in the example problems in the text. The many uses of these spreadsheets are illustrated throughout the text. At the end of most chapters are example problems demonstrating the use of the spreadsheet for that particular chapter. Space does not permit examples for all of the spreadsheet capabilities. The examples chosen were thought by the authors to be the most relevant.

Visit the Student Companion Site portion of the book website at www.wiley.com/college/mccormac to download this software.

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Jack C. McCormac
Russell H. Brown

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Introduction

CHAPTER 1

1.1 Concrete and Reinforced Concrete

Concrete is a mixture of sand, gravel, crushed rock, or other aggregates held together in a rocklike mass with a paste of cement and water. Sometimes one or more admixtures are added to change certain characteristics of the concrete such as its workability, durability, and time of hardening.

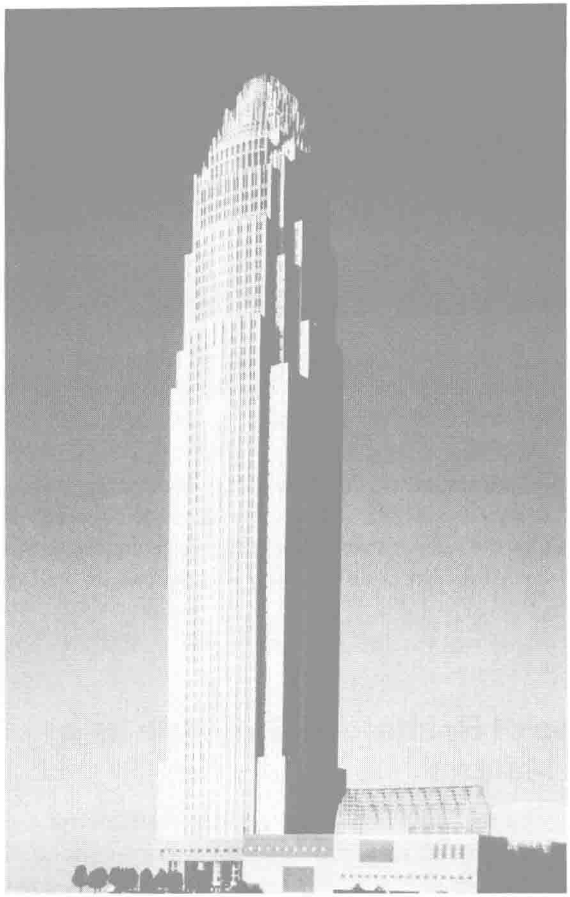
As with most rocklike substances, concrete has a high compressive strength and a very low tensile strength. *Reinforced concrete* is a combination of concrete and steel wherein the steel reinforcement provides the tensile strength lacking in the concrete. Steel reinforcing is also capable of resisting compression forces and is used in columns as well as in other situations, which are described later.

1.2 Advantages of Reinforced Concrete as a Structural Material

Reinforced concrete may be the most important material available for construction. It is used in one form or another for almost all structures, great or small—buildings, bridges, pavements, dams, retaining walls, tunnels, drainage and irrigation facilities, tanks, and so on.

The tremendous success of this universal construction material can be understood quite easily if its numerous advantages are considered. These include the following:

1. It has considerable compressive strength per unit cost compared with most other materials.
2. Reinforced concrete has great resistance to the actions of fire and water and, in fact, is the best structural material available for situations where water is present. During fires of average intensity, members with a satisfactory cover of concrete over the reinforcing bars suffer only surface damage without failure.
3. Reinforced concrete structures are very rigid.
4. It is a low-maintenance material.
5. As compared with other materials, it has a very long service life. Under proper conditions, reinforced concrete structures can be used indefinitely without reduction of their load-carrying abilities. This can be explained by the fact that the strength of concrete does not decrease with time but actually increases over a very long period, measured in years, because of the lengthy process of the solidification of the cement paste.
6. It is usually the only economical material available for footings, floor slabs, basement walls, piers, and similar applications.
7. A special feature of concrete is its ability to be cast into an extraordinary variety of shapes from simple slabs, beams, and columns to great arches and shells.



NCNB Tower in Charlotte, North Carolina, completed 1991.

8. In most areas, concrete takes advantage of inexpensive local materials (sand, gravel, and water) and requires relatively small amounts of cement and reinforcing steel, which may have to be shipped from other parts of the country.

9. A lower grade of skilled labor is required for erection as compared with other materials such as structural steel.

1.3 Disadvantages of Reinforced Concrete as a Structural Material

To use concrete successfully, the designer must be completely familiar with its weak points as well as its strong ones. Among its disadvantages are the following:

1. Concrete has a very low tensile strength, requiring the use of tensile reinforcing.

2. Forms are required to hold the concrete in place until it hardens sufficiently. In addition, falsework or shoring may be necessary to keep the forms in place for roofs, walls, floors, and similar structures until the concrete members gain sufficient strength to support themselves. Formwork is very expensive. In the United States, its costs run from one-third to two-thirds of the total cost of a reinforced concrete structure, with average