DESIGN OF REINFORCED CONCRETE

NINTH EDITION

JACK C. McCORMAC • RUSSELL H. BROWN

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ACI 318-11 Code Edition

Jack C. McCormac
Clemson University

Russell H. Brown
Clemson University

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Brief Contents

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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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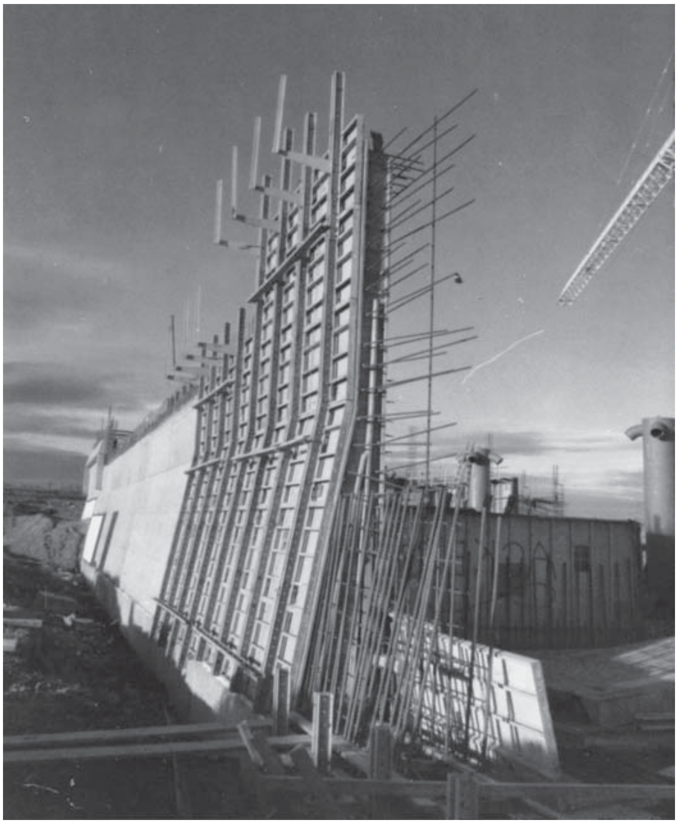
JACK C. MCCORMAC
RUSSELL H. BROWN


Courtesy of The Burke Company.

Sewage treatment plant, Redwood City, California.

Live load reductions are permitted, according to Section 4.8 of ASCE 7, because is it unlikely that the entire structure will be subjected to its full design live load over its entire floor area all at one time. This reduction can significantly reduce the total design live load on a structure, resulting in much lower column loads at lower floors and footing loads.

1.24 Environmental Loads

Environmental loads are loads caused by the environment in which the structure is located. For buildings, they are caused by rain, snow, wind, temperature change, and earthquake. Strictly speaking, these are also live loads, but they are the result of the environment in which the structure is located. Although they do vary with time, they are not all caused by gravity or operating conditions, as is typical with other live loads. In the next few paragraphs, a few comments are made about the various kinds of environmental loads.

1. *Snow and ice.* In the colder states, snow and ice loads are often quite important. One inch of snow is equivalent to approximately 0.5 psf, but it may be higher at lower elevations where snow is denser. For roof designs, snow loads of from 10 psf to 40 psf are used, the magnitude depending primarily on the slope of the roof and to a lesser degree on the character of the roof surface. The larger values are used for flat roofs, the smaller ones for sloped roofs. Snow tends to slide off sloped roofs, particularly those with metal or slate surfaces. A load of approximately 10 psf might be used for 45° slopes, and a 40-psf load might be used for flat

Example 3.6

Repeat Example 3.3 using the Excel spreadsheet provided for Chapter 3.

SOLUTION

Open the Chapter 3 spreadsheet and the Rectangular Beam worksheet. Enter values only in the cells highlighted yellow. The spreadsheet displays a message, "code violation . . . too much steel." This is an indication that the beam violates ACI Section 10.3.5 and is not ductile. This beam is not allowed by the ACI Code.

Example 3.7

Repeat Example 3.4 using the Excel spreadsheet provided for Chapter 3.

SOLUTION

Open the Chapter 3 spreadsheet and the Rectangular Beam worksheet. Enter values only in the cells highlighted yellow. The final result is $\phi M_n = 154.5$ ft-k (nearly the same answer as Example 3.4). The ϕ factor is also nearly the same as Example 3.4 (0.0834 compared with 0.0836). The difference is the result of the spreadsheet using the more general value for ϵ_y of $f_y/E_s = 0.00207$ instead of the approximate value of 0.002 permitted by the code for Grade 60 reinforcing steel. A difference of this magnitude is not important, as discussed in Section 1.25, "Calculation Accuracy."

PROBLEMS

Problem 3.1 What are the advantages of the strength design method as compared to the allowable stress or alternate design method?

Problem 3.2 What is the purpose of strength reduction factors? Why are they smaller for columns than for beams?

Problem 3.3 What are the basic assumptions of the strength design theory?

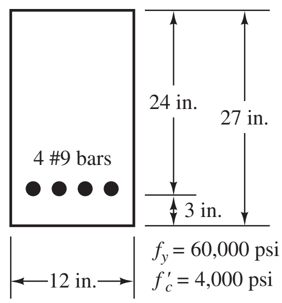
Problem 3.4 Why does the ACI Code specify that a certain minimum percentage of reinforcing be used in beams?

Problem 3.5 Distinguish between tension-controlled and compression-controlled beams.

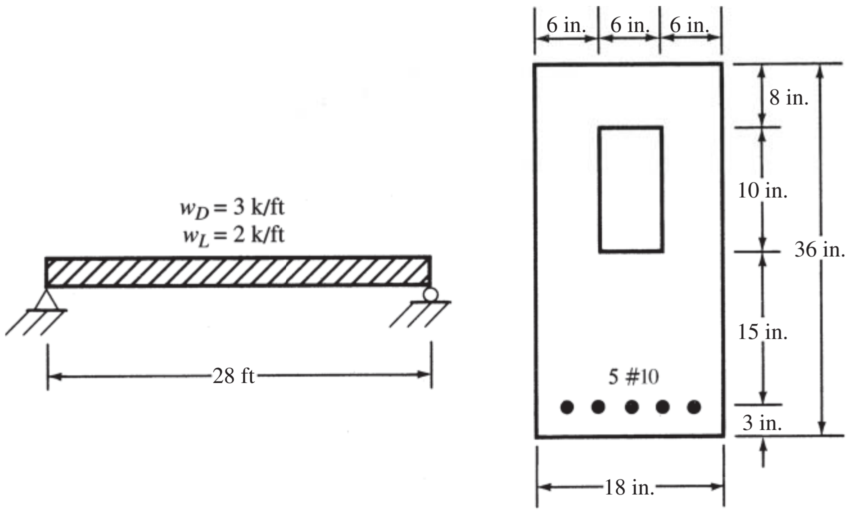
Problem 3.6 Explain the purpose of the minimum cover requirements for reinforcing specified by the ACI Code.

For Problems 3.7 to 3.9, determine the values of ϵ_t, ϕ, and ϕM_n for the sections shown.

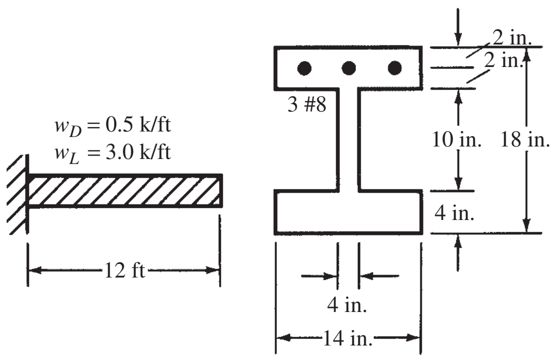
Problem 3.7 (*Ans.* $\phi M_n = 379.1$ ft-k)



Problem 6.8



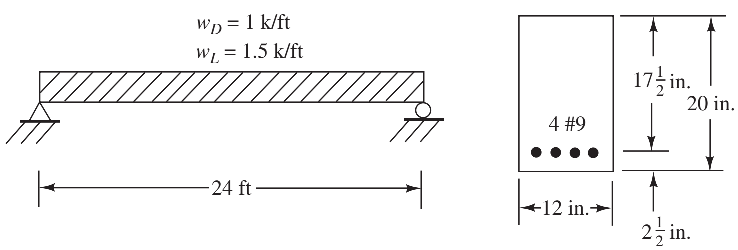
Problem 6.9 (*Ans.* 1.54 in.)



Problem 6.10 Repeat Problem 6.8 if a 25-k concentrated live load is added at the centerline of the span.

For Problems 6.11 and 6.12, calculate the instantaneous deflections and the long-term deflections after four years, assuming that 30% of the live loads are continuously applied for 48 months. $f_y = 60{,}000$ psi, $f'_c = 4000$ psi, and $n = 8$.

Problem 6.11 (*Ans.* Instantaneous δ for full $w_D + w_L = 1.056$ in., long-term $\delta = 1.832$ in.)



to be #3 or larger in size, and they must have diameters no less than 0.042 times the stirrup spacings (ACI 11.5.6.2).

5. Torsional reinforcing must be provided for a distance no less than $b_t + d$ beyond the point where it is theoretically no longer required. The term b_t represents the width of that part of the member cross section which contains the closed torsional stirrups (ACI 11.5.6.3).

15.9 Example Problems Using U.S. Customary Units

In this section, the design of torsional reinforcing for a beam is presented using U.S. customary units; an example using SI units is presented in the next section.

Example 15.1

Design the torsional reinforcing needed for the beam shown in Figure 15.13 if $f'_c = 4000$ psi, $f_y = 60{,}000$ psi, $T_u = 30$ ft-k, and $V_u = 60$ k. Assume 1.5-in. clear cover, #4 stirrups, and a required A_s for M_u of 3.52 in.^{2}. Select #8 bars for flexural reinforcing. Normal-weight concrete is specified.

SOLUTION

1. Is Torsion Reinforcing Needed?

A_{cp} = area enclosed by outside perimeter of concrete cross section $= (16)(26) = 416$ in.^{2} (the letter c stands for concrete, and the letter p stands for perimeter of cross section)

$$p_{cp} = \text{outside perimeter of the cross section} = (2)(16\text{ in.} + 26\text{ in.}) = 84\text{ in.}$$

Torsion, T_u, can be neglected if less than

$$\phi\lambda\sqrt{f'_c}\frac{A_{cp}^2}{p_{cp}} = (0.75)(1.0)(\sqrt{4000}\text{ psi})\left[\frac{(416\text{ in.}^2)^2}{84\text{ in.}}\right]$$

$$= 97{,}723\text{ in-lb} = 97.72\text{ in-k} < 30\text{ ft-k} \times 12\text{ in/ft} = 360\text{ in-k}$$

$\therefore$ Torsion must be considered

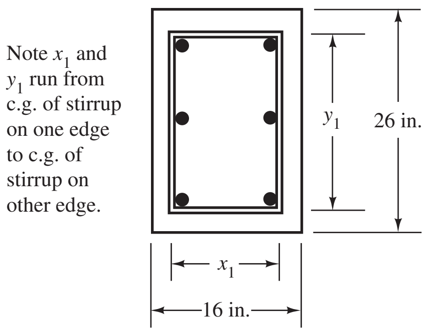


FIGURE 15.13 Beam cross section for Example 15.1.