



An ACI Handbook

The Reinforced Concrete Design Handbook

A Companion to *ACI 318-14*

Volume 2: Special Topics
SP-17(14)



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THE REINFORCED CONCRETE DESIGN HANDBOOK

A Companion to *ACI 318-14*

VOLUME 1

BUILDING EXAMPLE

STRUCTURAL SYSTEMS

STRUCTURAL ANALYSIS

DURABILITY

ONE-WAY SLABS

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BEAMS

DIAPHRAGMS

COLUMNS

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STRUT-AND-TIE MODEL

ANCHORING TO CONCRETE

**ACI SP-17(14)
Volume 2**

**THE REINFORCED CONCRETE
DESIGN HANDBOOK**

A Companion to *ACI 318-14*

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First Printing
September 2015
ISBN: 978-1-942727-38-5

THE REINFORCED CONCRETE DESIGN HANDBOOK Volume 2 ~ Ninth Edition

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DEDICATION



This edition of *The Reinforced Concrete Design Handbook, SP-17(14)*, is dedicated to the memory of Daniel W. Falconer and his many contributions to the concrete industry. He was Managing Director of Engineering for the American Concrete Institute from 1998 until his death in July 2015.

Dan was instrumental in the reorganization of *Building Code Requirements for Structural Concrete (ACI 318-14)* and *Commentary (ACI 318R-14)* as he served as ACI staff liaison to ACI Committee 318, Structural Concrete Building Code; and ACI Subcommittee 318-SC, Steering Committee. His vision was to simplify the use of the Code for practitioners and to illustrate the benefits of the reorganization with this major revision of *SP-17*. His oversight and review comments were instrumental in the development of this Handbook.

An ACI member since 1982, Dan served on ACI Committees 344, Circular Prestressed Concrete Structures, and 373, Circular Concrete Structures Prestressed with Circumferential Tendons. He was also a member of the American Society of Civil Engineers. Prior to joining ACI, Dan held several engineering and marketing positions with VSL Corp. Before that, he was Project Engineer for Skidmore, Owings, and Merrill in Washington, DC. He received his BS in civil engineering from the University of Buffalo, Buffalo, NY and his MS in civil and structural engineering from Lehigh University, Bethlehem, PA. He was a licensed professional engineer in several states.

In his personal life, Dan was an avid golfer, enjoying outings with his three brothers whenever possible. He was also an active member of Our Savior Lutheran Church in Hartland, MI, and a dedicated supporter and follower of the Michigan State Spartans basketball and football programs. Above all, Dan was known as a devoted family man dedicated to his wife of 33 years, Barbara, his children Mark, Elizabeth, Kathryn, and Jonathan, and two grandsons Samuel and Jacob.

In his memory, the ACI Foundation has established an educational memorial. For more information visit <http://www.scholarshipcouncil.org/Student-Awards>. Dan will be sorely missed for many years to come.

FOREWORD

The Reinforced Concrete Design Handbook provides assistance to professionals engaged in the design of reinforced concrete buildings and related structures. This edition is a major revision that brings it up-to-date with the approach and provisions of *Building Code Requirements for Structural Concrete (ACI 318-14)*. The layout and look of the Handbook have also been updated.

The Reinforced Concrete Design Handbook now provides dozens of design examples of various reinforced concrete members, such as one- and two-way slabs, beams, columns, walls, diaphragms, footings, and retaining walls. For consistency, many of the numerical examples are based on a fictitious seven-story reinforced concrete building. There are also many additional design examples not related to the design of the members in the seven story building that illustrate various *ACI 318-14* requirements.

Each example starts with a problem statement, then provides a design solution in a three column format—code provision reference, short discussion, and design calculations— followed by a drawing of reinforcing details, and finally a conclusion elaborating on a certain condition or comparing results of similar problem solutions.

In addition to examples, almost all chapters in the *Reinforced Concrete Design Handbook* contain a general discussion of the related *ACI 318-14* chapter.

All chapters were developed by ACI staff engineers under the auspices of the ACI Technical Activities Committee (TAC). To provide immediate oversight and guidance for this project, TAC appointed three content editors: Andrew Taylor, Trey Hamilton III, and Antonio Nanni. Their reviews and suggestions improved this publication and are appreciated. TAC also appreciates the support of Dirk Bondy and Kenneth Bondy who provided free software to analyze and design the post-tensioned beam example, in addition to valuable comments and suggestions. Thanks also go to JoAnn Browning, David DeValve, Anindya Dutta, Charles Dolan, Matthew Huslig, Ronald Klemencic, James Lai, Steven McCabe, Mike Mota, Hani Nassif, Jose Pincheira, David Rogowski, and Siamak Sattar, who reviewed one or more of the chapters.

Special thanks go to StructurePoint and Computers and Structures, Inc. (SAP 2000 and Etabs) for providing a free copy of their software to perform analyses of structure and members.

Special thanks also go to Stuart Nielsen, who provided the cover art using SketchUp.

The Reinforced Concrete Design Handbook is published in two volumes: Chapters 1 through 11 are published in Volume 1 and Chapters 12 through 15 are published in Volume 2. Design aids and a moment interaction diagram Excel spreadsheet are available for free download from the following ACI webpage links:

<https://www.concrete.org/store/productdetail.aspx?ItemID=SP1714DAE>

<https://www.concrete.org/store/productdetail.aspx?ItemID=SP1714DA>

Keywords: anchoring to concrete; beams; columns; cracking; deflection; diaphragm; durability; flexural strength; footings; frames; piles; pile caps; post-tensioning; punching shear; retaining wall; shear strength; seismic; slabs; splicing; stiffness; structural analysis; structural systems; strut-and-tie; walls.

Khaled Nahlawi
Managing Editor

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CHAPTER 12—RETAINING WALLS

12.1—General

A retaining or cantilevered wall is a structural system that provides horizontal resistance to a soil mass and prevents it from assuming its natural slope. A retaining wall consists of a vertical stem and a horizontal footing (heel and toe). The stem provides horizontal resistance to the soil behind the wall, which is at higher elevation than the soil in front of the wall. The footing toe and heel transfers the lateral soil pressure to the soil strata under the retaining wall (Fig. 12.1a (a)). If retaining walls are placed close to property borderlines, the toe or heel can be eliminated (refer to Fig. 12.1a (b) and (c)).

Reinforced concrete stems are designed to withstand horizontal soil pressures and surcharge loads. Earthquake loads for retaining walls are not addressed in this Handbook.

For the purposes of this chapter, it is assumed that the geotechnical report states that the retaining wall geometry within the surrounding soil is stable provided specified factors of safety (FS) are observed. Failure of a retaining wall due to sliding, overturning, or bearing (Fig. 12.1b) is associated with the interaction between the retaining wall

geometry and the local soil properties. Traditional FS against these soil-related failures are shown as follows:

- (a) $FS \geq 1.5$: against sliding failure
- (b) $FS \geq 2.0$: against overturning failure
- (c) $FS \geq 3.0$: against bearing failure

These factors are usually provided by the geotechnical engineer and are not in the scope of this guide.

The reinforced concrete stem and footing flexure and shear design strength must be at least equal to the factored moments and shears determined from the analysis. Figure 12.1c depicts the deflected shape under load of the stem, heel, toe, and key and related tension areas (shown by cracks):

In situations where the factor of safety against sliding failure is low, and there are site constraints against lengthening the heel, a “key” can be constructed below the footing to increase sliding resistance, as shown in Fig. 12.1d.

Typical retaining walls vary in height between 5 and 20 ft. For retaining walls beyond 20 ft, buttresses or counterforts are usually provided. Counterforts are normally preferred as they create clean and an unobstructed view from the stem face (Fig. 12.1e).

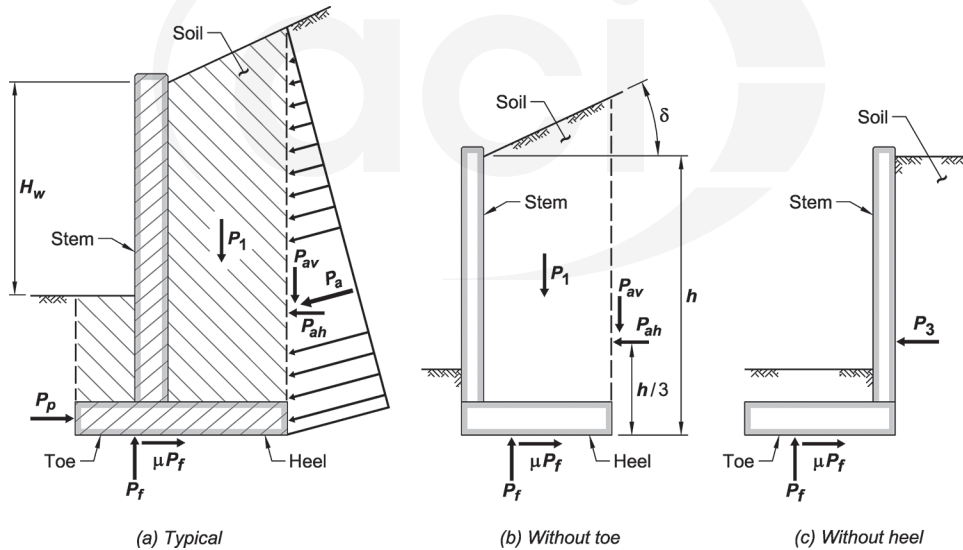


Fig. 12.1a—Retaining or cantilever wall types.

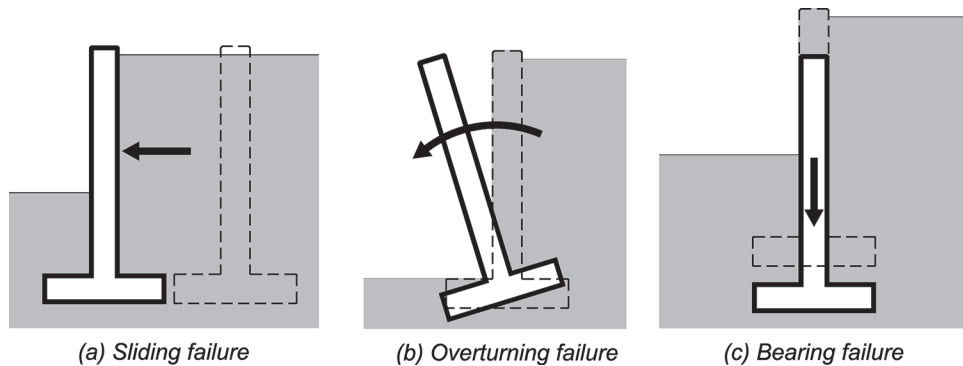


Fig. 12.1b—Cantilever wall soil failure modes.