

Guide to Simplified Design for Reinforced Concrete Buildings

(For Buildings of Limited Size and Height,
based on ACI 318-14 and ACI IPS-1, “Essential
Requirements for Reinforced Concrete
Buildings”)

Reported by ACI Committee 314

ACI 314R-16



American Concrete Institute
Always advancing



Guide to Simplified Design for Reinforced Concrete Buildings

Copyright by the American Concrete Institute, Farmington Hills, MI. All rights reserved. This material may not be reproduced or copied, in whole or part, in any printed, mechanical, electronic, film, or other distribution and storage media, without the written consent of ACI.

The technical committees responsible for ACI committee reports and standards strive to avoid ambiguities, omissions, and errors in these documents. In spite of these efforts, the users of ACI documents occasionally find information or requirements that may be subject to more than one interpretation or may be incomplete or incorrect. Users who have suggestions for the improvement of ACI documents are requested to contact ACI via the errata website at <http://concrete.org/Publications/DocumentErrata.aspx>. Proper use of this document includes periodically checking for errata for the most up-to-date revisions.

ACI committee documents are intended for the use of individuals who are competent to evaluate the significance and limitations of its content and recommendations and who will accept responsibility for the application of the material it contains. Individuals who use this publication in any way assume all risk and accept total responsibility for the application and use of this information.

All information in this publication is provided “as is” without warranty of any kind, either express or implied, including but not limited to, the implied warranties of merchantability, fitness for a particular purpose or non-infringement.

ACI and its members disclaim liability for damages of any kind, including any special, indirect, incidental, or consequential damages, including without limitation, lost revenues or lost profits, which may result from the use of this publication.

It is the responsibility of the user of this document to establish health and safety practices appropriate to the specific circumstances involved with its use. ACI does not make any representations with regard to health and safety issues and the use of this document. The user must determine the applicability of all regulatory limitations before applying the document and must comply with all applicable laws and regulations, including but not limited to, United States Occupational Safety and Health Administration (OSHA) health and safety standards.

Participation by governmental representatives in the work of the American Concrete Institute and in the development of Institute standards does not constitute governmental endorsement of ACI or the standards that it develops.

Order information: ACI documents are available in print, by download, on CD-ROM, through electronic subscription, or reprint and may be obtained by contacting ACI.

Most ACI standards and committee reports are gathered together in the annually revised ACI Manual of Concrete Practice (MCP).

American Concrete Institute
38800 Country Club Drive
Farmington Hills, MI 48331
Phone: +1.248.848.3700
Fax: +1.248.848.3701

www.concrete.org

Guide to Simplified Design for Reinforced Concrete Buildings

(For Buildings of Limited Size and Height, based on ACI 318-14 and ACI IPS-1, “Essential Requirements for Reinforced Concrete Buildings”)

Reported by ACI Committee 314

Michael C. Mota, Chair

Esteban Anzola, Secretary

John Aidoo
Iyad M. Alsamsam
JoAnn P. Browning
James R. Cagley
Omar D. Cardona
Julian Carrillo
W. Gene Corley
Om P. Dixit

David A. Fanella
Yosef Farbiarz
Luis E. García
Jose M. Izquierdo-Encarnación
Mahmoud E. Kamara
Jason J. Krohn
James S. Lai
Lionel A. Lemay

Andres Lepage
Adolfo B. Matamoros
Mustafa Mahamid
Lila Gabriela Mendez Florez
Javeed Munshi
T. George Muste
Ronald L. O'Connell
Guney Ozcebe

Viral B. Patel
Santiago Pujol
William E. Rushing Jr.
Guillermo Santana
Jorge I. Segura
Larbi M. Sennour
Dorian P. Tung
Jairo Uribe

Special acknowledgment to J. P. Browning, L. E. García, J. M. Izquierdo-Encarnación, J. S. Lai, M. C. Mota, S. Pujol, and J. I. Segura for their contributions to this guide.

This document is dedicated to the memory of late subcommittee member W. Gene Corley.

This guide presents simplified methods and design techniques that facilitate and speed the engineering of low-rise buildings within certain limitations. Material is presented in an order that follows typical design process with procedures introduced as the designer will need them in the course of a building design. Much of the information presented in this guide is derived from ACI 318, ACI 308, ACI 307, and the 2015 International Building Code (IBC) (International Code Council 2015). The quality and testing of materials used in construction are covered by references to the appropriate ASTM standard specifications.

Whereas many of the tables, charts, and values included in this guide originated from the aforementioned reference documents, they have been modified or reorganized to be more conservative, to match design process flow, or better support the holistic and simplified design approach presented.

Although this guide is not written in mandatory language, the information is presented in such a manner that a structure designed following this guide will, in principle, comply with the codes and

standards on which it was based. Although this guide is written in non-mandatory language, it is meant to be applied as a whole, because the simplified provisions are interdependent, and it would be unsafe to employ only a portion of this guide and disregard the remainder. This guide is not a code and is not deemed to satisfy ACI 318, ASCE 7, and the International Building Code (International Code Council 2015). This guide is expected to be especially useful in the education and training of engineers in reinforced concrete design of low-rise structures of small to medium floor areas.

There are many options within these standards that are not considered in this guide, such as the use of supplementary cementitious materials in concrete mixtures. As this guide will be used as a design aid, it is the licensed design professional's responsibility to ensure that the structure design satisfies the requirements of ACI 318, ASCE 7, the International Building Code (International Code Council 2015), and the legal requirements of the local jurisdiction. The original draft of the guide, published as ACI IPS-1 (2002), was produced by a Joint Committee of Instituto Colombiano de Normas Técnicas y Certificación (Colombian Institute for Technical Standards and Certification) (ICONTEC) and Asociación Colombiana de Ingeniería Sísmica (Colombian Association for Earthquake Engineering) (AIS).

The initial drafting of ACI IPS-1 (2002) was motivated by frequent worldwide discussions that reinforced concrete codes might be unnecessarily sophisticated for some applications, such as small low-rise buildings. Current knowledge of reinforced concrete behavior obtained through experimentation and experi-

ACI Committee Reports, Guides, and Commentaries are intended for guidance in planning, designing, executing, and inspecting construction. This document is intended for the use of individuals who are competent to evaluate the significance and limitations of its content and recommendations and who will accept responsibility for the application of the material it contains. The American Concrete Institute disclaims any and all responsibility for the stated principles. The Institute shall not be liable for any loss or damage arising therefrom.

Reference to this document shall not be made in contract documents. If items found in this document are desired by the Architect/Engineer to be a part of the contract documents, they shall be restated in mandatory language for incorporation by the Architect/Engineer.

ACI 314R-16 supersedes ACI 314R-11 and became effective June 2016.

Copyright © 2016, American Concrete Institute.

All rights reserved including rights of reproduction and use in any form or by any means, including the making of copies by any photo process, or by electronic or mechanical device, printed, written, or oral, or recording for sound or visual reproduction or for use in any knowledge or retrieval system or device, unless permission in writing is obtained from the copyright proprietors.

ence, and its status and dissemination as a structural material used worldwide, made developing a simplified design and construction guide feasible. This guide used *ACI IPS-1 (2002)* as a basis, with information derived from *ACI 318*, *ASCE 7*, and the *International Building Code (International Code Council 2015)*.

This guide presents simplified approaches to assist engineers in designing low-rise buildings within certain limitations, in addition to the following:

- (a) Information on the order needed in the course of a design
- (b) Explanatory material at appropriate places
- (c) Computations only requiring a hand calculator
- (d) Graphs and graphical explanations
- (e) Design information based on simplified strength models
- (f) Other limit states accounted for by minimum dimensions
- (g) Conservative loads and simplified analysis guidelines
- (h) Simplified geotechnical information to help define soil-bearing capacity
- (i) Shear walls as the seismic-force-resisting system
- (j) Material and construction guidelines based on commonly available steel grades and medium-strength concrete that can be site mixed.

Keywords: concrete quality; foundation design; frame analysis; inspection; low-rise building construction; low-rise structure; mixing; placing; section analysis; seismic design; simplified design; specifications; structure design; structure layout.

CONTENTS

CHAPTER 1—GENERAL, p. 3

- 1.1—Scope, p. 3
- 1.2—Purpose, p. 3
- 1.3—Limitations, p. 3
- 1.4—Supporting codes and standards, p. 4
- 1.5—Design and construction procedure, p. 5
- 1.6—Limit states, p. 6
- 1.7—Strength design, p. 6
- 1.8—Serviceability design, p. 7

CHAPTER 2—NOTATION AND DEFINITIONS, p. 7

- 2.1—Notation, p. 7
- 2.2—Definitions, p. 10

CHAPTER 3—STRUCTURAL SYSTEM LAYOUT, p. 14

- 3.1—Description of structural components, p. 14
- 3.2—General, p. 15
- 3.3—Structural layout, p. 15
- 3.4—Feasibility of guide usage, p. 16

CHAPTER 4—LOADS, p. 16

- 4.1—General, p. 16
- 4.2—Load factors and load combinations, p. 16
- 4.3—Mass and weight, p. 17
- 4.4—Weight of materials, p. 17
- 4.5—Dead loads, p. 17
- 4.6—Live loads, p. 21
- 4.8—Rain load, p. 22
- 4.9—Snow load, p. 22
- 4.10—Wind loads, p. 22
- 4.12—Soil weight and lateral pressure, p. 26

- 4.13—Lateral loads, p. 26
- 4.14—Lateral-force-resisting system, p. 27
- 4.15—Minimum amount of reinforced concrete structural walls, p. 29

CHAPTER 5—GENERAL REINFORCED CONCRETE INFORMATION, p. 31

- 5.1—Scope, p. 31
- 5.2—Materials for reinforced concrete, p. 31
- 5.3—Minimum and maximum reinforcing bar diameter, p. 31
- 5.5—Minimum reinforcement bend diameter, p. 32
- 5.8—Development length, lap splicing, and anchorage of reinforcement, p. 34
- 5.9—Longitudinal reinforcement, p. 34
- 5.10—Transverse reinforcement, p. 35
- 5.11—Flexure, p. 35
- 5.12—Axial loads with or without flexure, p. 36
- 5.13—Shear, p. 37
- 5.14—Bearing, p. 39

CHAPTER 6—FLOOR SYSTEMS, p. 39

- 6.1—Types of floor systems, p. 39
- 6.2—Selection of floor system, p. 42
- 6.3—Structural integrity, p. 42
- 6.4—One-way and two-way load paths, p. 42
- 6.5—Minimum depth for floor system members, p. 42
- 6.6—Clear dimensions for floor system, p. 44
- 6.7—Floor finish, p. 44
- 6.8—Ducts, shafts, openings, and embedded piping, p. 44

CHAPTER 7—SOLID SLABS SUPPORTED ON GIRDERS, BEAMS, JOISTS, OR REINFORCED CONCRETE WALLS, p. 45

- 7.1—General, p. 45
- 7.2—Loads, p. 45
- 7.3—Reinforcement details, p. 45
- 7.4—Shear strength, p. 47
- 7.5—Slab between joists, p. 47
- 7.6—Cantilevers of slabs supported on girders, beams, or walls, p. 48
- 7.7—One-way, single-span solid slabs spanning between girders, beams, or reinforced concrete walls, p. 49
- 7.8—One-way solid slabs supported on girders, beams, or walls with two or more spans, p. 50
- 7.9—Two-way solid slabs spanning between girders, beams, or reinforced concrete walls, p. 51

CHAPTER 8—GIRDERS, BEAMS, AND JOISTS, p. 59

- 8.1—General, p. 59
- 8.2—Loads, p. 59
- 8.3—Reinforcement types, p. 59
- 8.4—Longitudinal reinforcement, p. 60
- 8.5—Transverse reinforcement, p. 64
- 8.6—Joists and beams supported by girders, p. 66
- 8.7—Girders that are part of a frame, p. 70

CHAPTER 9—SLAB-COLUMN SYSTEMS, p. 72

- 9.1—General, p. 72
- 9.2—Loads, p. 72
- 9.3—Dimensional limits, p. 73
- 9.4—Reinforcement details, p. 74
- 9.5—Shear strength, p. 76
- 9.6—Minimum slab thickness as required by punching shear, p. 77
- 9.7—Minimum slab thickness as required by beam action, p. 77
- 9.8—Flexure, p. 78
- 9.9—Calculation of support reactions, p. 80

CHAPTER 10—COLUMNS, p. 80

- 10.1—General, p. 80
- 10.2—Loads, p. 80
- 10.3—Dimensional limits, p. 81
- 10.4—Reinforcement details, p. 82
- 10.5—Flexure, p. 86
- 10.6—Shear, p. 86
- 10.7—Calculation of foundation reaction, p. 87

CHAPTER 11—SEISMIC RESISTANCE, p. 87

- 11.1—Special reinforcement details for seismic zones, p. 87
- 11.2—Interaction with nonstructural elements, p. 93

CHAPTER 12—REINFORCED CONCRETE WALLS, p. 94

- 12.1—General, p. 94
- 12.2—Loads, p. 94
- 12.3—Dimensional limits, p. 95
- 12.4—Reinforcement details, p. 95
- 12.5—Flexure, p. 97
- 12.6—Shear, p. 97
- 12.7—Calculation of reactions at the foundation, p. 97
- 12.8—Core walls, p. 98

CHAPTER 13—OTHER STRUCTURAL MEMBERS, p. 98

- 13.1—Stairways and ramps, p. 98
- 13.2—Small water tanks (or potable water storage), p. 100

CHAPTER 14—FOUNDATIONS, p. 101

- 14.1—Soil investigation, p. 101
- 14.2—Allowable soil-bearing capacity, p. 101
- 14.3—Settlement criteria, p. 102
- 14.4—Dimensioning foundation members, p. 102
- 14.5—Spread footings, p. 102
- 14.6—Wall footings, p. 106
- 14.7—Combined footings, p. 107
- 14.8—Piles and caissons, p. 108
- 14.9—Footings on piles, p. 108
- 14.10—Foundation mats, p. 108
- 14.11—Retaining walls, p. 110
- 14.12—Grade beams (foundation beams), p. 114
- 14.13—Slabs-on-ground, p. 115

CHAPTER 15—DRAWINGS AND SPECIFICATIONS, p. 115

- 15.1—General, p. 115
- 15.2—Structural drawings, p. 116
- 15.3—Project specifications, p. 117

CHAPTER 16—CONSTRUCTION, p. 117

- 16.1—Introduction, p. 117
- 16.2—Concrete mixture proportioning, p. 118
- 16.4—Concrete mixing and transportation, p. 120
- 16.5—Concrete strength evaluation, p. 122
- 16.6—Concrete curing, p. 123
- 16.7—Form removal, p. 123

CHAPTER 17—REFERENCES, p. 124**APPENDIX A—COMPARISON OF ACI 314R-16 TO ACI 318-14, INTERNATIONAL BUILDING CODE (2015), AND ASCE 7-10, p. 125****CHAPTER 1—GENERAL****1.1—Scope**

This guide is intended for the planning, design, and construction of reinforced concrete structures in new low-rise buildings of restricted occupancy, number of stories, and area. Although the information presented was developed to produce, when properly used, a reinforced concrete structure with an appropriate margin of safety, this guide is not a replacement for a licensed design professional's experience and working knowledge. For the structure designed by this guide to attain the intended margin of safety, the guide should be used as a whole, and alternative procedures should be used only when explicitly permitted herein. The minimum dimensioning prescribed in the guide replace, in most cases, more detailed procedures prescribed in ACI 318, ASCE 7, and the International Building Code (International Code Council 2015).

1.2—Purpose

This guide provides a licensed design professional with sufficient information to design structural reinforced concrete members that comprise the structural framing of a low-rise building with the limits set in 1.3. Design rules set forth in this guide are simplifications that, when used together, comply with the more detailed requirements of ACI 318, ASCE 7, and the International Building Code (International Code Council 2015).

1.3—Limitations

This guide is only meant for buildings meeting all the limitations set forth in 1.3.1 to 1.3.10. These limits maintain the guide scope in close adherence to the collective experience of the original drafting committee (ICONTEC-AIS). Buildings within this scope are expected to have a normal rectangular footprint with simple standard geometries and member dimensions in both plan and vertical directions. Such buildings also depend primarily on reinforced concrete