

Guide to Design Detailing to Mitigate Cracking

Reported by ACI Committee 224



American Concrete Institute®
Advancing concrete knowledge

First Printing
December 2013

Guide to Design Detailing to Mitigate Cracking

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 www.concrete.org/committees/errata.asp. 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
U.S.A.
Phone: 248-848-3700
Fax: 248-848-3701**

www.concrete.org

ISBN: 978-0-87031-856-6

Guide to Design Detailing to Mitigate Cracking

Reported by ACI Committee 224

Jeffrey S. West*, Chair

Jacob K. Bice, Secretary

Florian G. Barth*
Peter H. Bischoff
David Darwin
John F. Duntemann
Christopher C. Ferraro
Fouad H. Fouad
David W. Fowler
Robert J. Frosch

Grant T. Halvorsen
Will Hansen*
Harvey H. Haynes*
Mohammad Iqbal
Ralf Leistikow*
Malcolm K. Lim
Edward G. Nawy
Kamran M. Nemati

Keith A. Pashina
Randall W. Poston*
Guillermo Alberto Riveros
John W. Roberts
Andrew Scanlon
Andrea J. Schokker
Consulting Members
Julius G. Potyondy

Royce J. Rhoads
Ernest K. Schrader

*Members of the committee who prepared this report.

Special acknowledgement to Paul Hedli for his contribution to this report.

Recommendations made in this guide offer performance-based details that can mitigate and control concrete cracking. Structural elements are reviewed individually to identify crack causation and to offer design and detailing recommendations to mitigate crack development. In addition, standard details for various structural members within a building are offered that have been used effectively to mitigate and control crack development in concrete members.

Keywords: cast-in-place; crack mitigation; crack control; cracking; detailing; environmental structure; foundation; prestressed; reinforcement; restraint; shrinkage; slab; tensile stress; thermal effects; wall.

CONTENTS

CHAPTER 1—INTRODUCTION AND SCOPE, p. 2

- 1.1—Introduction, p. 2
- 1.2—Objective, p. 2
- 1.3—Scope, p. 2

CHAPTER 2—NOTATION AND DEFINITIONS, p. 2

- 2.1—Notation, p. 2
- 2.2—Definitions, p. 3

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.

CHAPTER 3—DESIGN-DETAILING CONSIDERATIONS, p. 3

- 3.1—Concrete member type and reinforcement, p. 3
- 3.2—Overall and local regions, p. 3
- 3.3—Framing compatibility, p. 3

CHAPTER 4—DETAILED OF TWO-WAY REINFORCED CONCRETE SLAB SYSTEMS, p. 3

- 4.1—General, p. 3
- 4.2—Causes and types of restraint cracking, p. 3
- 4.3—Crack mitigation and control, p. 5

CHAPTER 5—DETAILED OF ONE-WAY REINFORCED CONCRETE SLAB SYSTEMS, p. 9

- 5.1—General, p. 9
- 5.2—Causes and types of restraint cracking, p. 10
- 5.3—Crack mitigation and control, p. 11

CHAPTER 6—DETAILED OF COLUMNS, p. 12

- 6.1—General, p. 12
- 6.2—Short columns, p. 12
- 6.3—Columns between walls, p. 13
- 6.4—Corner and exterior columns, p. 13
- 6.5—Slender columns, p. 13
- 6.6—Multistory columns, p. 13
- 6.7—Column/slab joints, p. 14
- 6.8—Oversized or unique-shaped columns (architectural columns), p. 14

ACI 224.4R-13 was adopted and published December 2013.

Copyright © 2013, 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.

CHAPTER 7—DETAILING OF WALLS, p. 15

- 7.1—Gravity load-bearing walls, p. 15
- 7.2—Non-load-bearing walls, p. 15
- 7.3—Shear walls, p. 15
- 7.4—Walls intended to contain liquid, p. 15

CHAPTER 8—DETAILING ON SLABS-ON-GROUND, p. 16

- 8.1—General, p. 16
- 8.2—Contraction joints, p. 16
- 8.3—Construction joints, p. 18
- 8.4—Expansion and isolation joints, p. 19

CHAPTER 9—REFERENCES, p. 20

Cited references, p. 20

CHAPTER 1—INTRODUCTION AND SCOPE**1.1—Introduction**

This guide addresses how to reduce potential cracking in reinforced concrete buildings in the design process through judicious consideration of building layout, selection of appropriate connections and joint types, and use of good reinforcement details. Each member within a structure may be subject to different types of cracks. Once the building design is developed, the type of framing system and its geometry selected, and appropriate code-required loads considered, it is then possible for the engineer to understand and identify the possible predominate crack development, crack types, and crack locations for each member within the structure. Predicting possible crack development for members within a building typically allows application of appropriate design details to mitigate and control cracking. Effective detailing of concrete members can improve strength, serviceability (deflection and durability), and aesthetics of a concrete structure.

The terms “crack mitigation” and “crack control” as used in this document have distinct meanings. Crack mitigation involves measures that are intended to prevent cracking from occurring. This includes concepts intended to minimize or eliminate restraint, such as consideration of building layout, the use of connection or element releases, or both. Crack control involves measures that are intended to control where cracks occur, or to limit the width and spacing of cracks. Crack control approaches include the use of joints and reinforcement detailing. The term “design details” in this document is a broad term intended to include all design measures intended to mitigate and control cracking.

Some of the crack mitigation and control measures described in this document involve reinforcement details and other requirements that may already be required by the Building Code for structural reasons. Other measures recommended in this document may require details and reinforcement amounts in excess of that required by ACI 315.

1.2—Objective

The *ACI Detailing Manual* (ACI Committee 315 2004) provides standard reinforcement details to aid the designer

in addressing concrete cracking. The *ACI Detailing Manual* shows individual details in isolation, which may be used for a particular member, joint, or cross section. In contrast, the objective of this document is to address the mitigation and control of cracking by considering the overall nature of a structure and how members may experience additional cross-sectional stresses due to the restraint caused by the structural system. The effect of the geometry and layout of the concrete framing system on the cracking of individual members or joints is discussed, and recommendations for more favorable arrangements of structural framing to minimize restraint are presented. Additionally, specific framing conditions where the cracking of a particular part of the structure is directly or indirectly affected by the neighboring elements or the overall framing system are discussed, and suggested reinforcement and release details to avoid or minimize such cracking are provided.

1.3—Scope

This document provides recommendations for design details and structural framing guidelines to mitigate, control, or distribute crack development in concrete members and structural systems. The recommendations and guidelines are presented in terms of concepts and effective practices that have been successfully implemented to mitigate and control cracking. Specific reinforcement details are presented for some situations, but not all, as the document is intended to illustrate concepts and approaches rather than to provide comprehensive details for all situations.

The reinforcement details shown in this document are for Grade 60 deformed steel reinforcing bars. Note that these reinforcement details may not be sufficient when other types of reinforcement are used, and in particular where the elastic properties (for example, fiber-reinforced polymer), bond properties, or strength of the bars are different.

This document specifically excludes the review of concrete member cracking due to unique or special materials used, concrete mixture proportions, or placing and finishing practices. The design details presented herein are limited to building structures and may not apply to special structures or nonbuilding structures. This document is limited to cast-in-place concrete frames only, not to precast concrete and masonry elements.

CHAPTER 2—NOTATION AND DEFINITIONS**2.1—Notation**

- S_1, S_2 = horizontal spacing of contraction joints in slabs on ground, in. (mm)
- S_{Dowel} = center-to-center spacing of dowel bars used for vertical joint load transfer in slabs on ground, in. (mm)
- S_{Plate} = center-to-center spacing of steel plates used for vertical joint load transfer in slabs on ground, in. (mm)
- ρ = steel reinforcement ratio