

ACI 445.1R-12

**Report on Torsion
in Structural Concrete**

Reported by Joint ACI-ASCE Committee 445



American Concrete Institute®



First Printing
April 2013

American Concrete Institute®
Advancing concrete knowledge

Report on Torsion in Structural Concrete

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
38801 Country Club Drive
Farmington Hills, MI 48331
U.S.A.
Phone: 248-848-3700
Fax: 248-848-3701

www.concrete.org

ISBN-13: 978-0-87031-810-8
ISBN: 0-87031-810-1

Report on Torsion in Structural Concrete

Reported by Joint ACI-ASCE Committee 445

Daniel A. Kuchma, Chair

Robert W. Barnes Jr., Secretary

Perry Adebar
Neal S. Anderson
Robert B. Anderson
Mark A. Ascheim
Oguzhan Bayrak
Zdenek P. Bazant
Abdeldjelil Belarbi**
Evan C. Bentz
John F. Bonacci

Hakim Bouadi
Michael D. Brown
Michael P. Collins
David Darwin
Walter H. Dilger*
Marc O. Eberhard
Catherine E. French
Robert J. Frosch
Gary G. Greene*

Neil M. Hawkins
Thomas T. C. Hsu*
Gary J. Klein
Zhongguo John Ma
Adolfo B. Matamoros
Denis Mitchell
Yi-Lung Mo*
Lawrence C. Novak
Carlos E. Ospina

Stavroula P. Papadopoulos
Maria Polak
Julia A. Kamirez
Karl-Franz Reineck
David H. Sanders*
Raj Valluvan
James K. Wight

*Subcommittee members who produced this report.

**Subcommittee Chair.

The committee would like to thank the following individuals for their contribution to this report: Mohammed Alkhrdaji, Neal S. Anderson, Shri Bhide, Michael D. Collins, Maria Cristina Vidigal de Lima, Leonard Elfgrén, Christos Karayannis, Liang-Jenq Leu, Mohammad Mansour, Basile Rabbat, M. Suleiman Rahal, and Paul Zia.

A clear understanding of the effects of torsion on concrete members is essential to the safe, economical design of reinforced and prestressed concrete members. This report begins with a brief and systematic summary of the 180-year history of torsion of structural concrete members, new and updated theories and their applications, and a historical overview outlining the development of research on torsion of structural concrete members. Historical theories and truss models include classical theories of Saint-Venant, and Bredt; the three-dimensional (3-D) space truss of Rausch; the equilibrium (plasticity) truss model of Melby as well as Lampert and Thürlimann; the compression field theory (CFT) by Collins and Mitchell; and the softened truss model (STM) by Hsu and Mo.

This report emphasizes that it is essential in the analysis of torsion in reinforced concrete that members should 1) satisfy the equilibrium condition (Mohr's stress circle); 2) obey the compatibility condition (Mohr's strain circle); and 3) establish the constitutive relationships of materials such as the "softened" stress-strain relationship of concrete and "smeared" stress-strain relationship of steel bars.

The behavior of members subjected to torsion combined with bending moment, axial load, and shear is discussed. This report deals with design issues, including compatibility torsion, spandrel beams, torsional limit design, open sections, and size effects. The final two chapters are devoted to the detailing requirements of transverse and longitudinal reinforcement in torsional members with detailed, step-by-step design examples for two beams under torsion using ACI (ACI 318-11), European (EC2-04), and Canadian Standards Association (CSA-A23.3-04) standards. Two design examples are given to illustrate the steps involved in torsion design. Design Example 1 is a rectangular reinforced concrete beam under pure torsion, and Design Example 2 is a prestressed concrete girder under combined torsion, shear, and flexure.

Keywords: combined action (loading); compatibility torsion; compression field theory; equilibrium torsion; interaction diagrams; prestressed concrete; reinforced concrete; shear flow zone; skew bending; softened truss model; spandrel beams; struts; torsion detailing; torsion redistribution; warping.

CONTENTS

CHAPTER 1—INTRODUCTION AND SCOPE, p. 2

- 1.1—Introduction, p. 2
- 1.2—Scope, p. 3

CHAPTER 2—NOTATION AND DEFINITIONS, p. 3

- 2.1—Notation, p. 3
- 2.2—Definitions, p. 5

ACI 445.1R-12 was adopted and published April 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.

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.