

ACI 441.1R-18

# Report on Equivalent Rectangular Concrete Stress Block and Transverse Reinforcement for High- Strength Concrete Columns

Reported by Joint ACI-ASCE Committee 441



American Concrete Institute  
*Always advancing*



## Report on Equivalent Rectangular Concrete Stress Block and Transverse Reinforcement for High-Strength Concrete Columns

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, 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 the ACI Collection of Concrete Codes, Specifications, and Practices.

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

[www.concrete.org](http://www.concrete.org)

# Report on Equivalent Rectangular Concrete Stress Block and Transverse Reinforcement for High-Strength Concrete Columns

Reported by Joint ACI-ASCE Committee 441

Sungjin Bae, Chair

Aly Said, Secretary

Ahmed Abd El Fattah  
Perry Adebar  
Shahria Alam  
Bassem Andrawes  
Oguzhan Bayrak  
Muhammad A. Cheema

Rami Eid  
Asad Esmaily  
Richard W. Furlong  
Wael Mohammed Hassan  
Riyadh A. Hindi  
Mahmoud E. Kamara

Tony C. Liu  
Mustafa A. Mahamid  
S. Ali Mirza  
Ronald L. O'Kane  
Patrick Paultre  
Hayder A. Raheer

Murat Saatcioglu  
Ayman E. Salama  
Halil Sezen  
Shamim A. Sheikh  
Nadim I. Wehbe

## Consulting Members

Alaa E. Elwi  
Esko Hyttinen

Said Iravani  
Chien-Hung Lin

Sankar Prasad  
L. Ramesh Murthy

*This report provides a research summary of equivalent rectangular concrete compressive stress blocks and transverse reinforcement design requirements for high-strength concrete (HSC) columns. Because ACI 318 code provisions for column design are mostly based on concrete strengths less than 10,000 psi (70 MPa), the use of equivalent rectangular concrete stress block factors given in the code has been questioned. As a result, many alternative expressions have been developed. This report provides a summary of various suggestions of equivalent rectangular concrete stress block and design guidelines for HSC columns.*

*The report also provides highlights of the research on the performance of HSC columns under various loading conditions, including monotonically increasing concentric and eccentric compression, and load reversals with increasing deformation and constant axial compression. The behavior of HSC columns subjected to combined axial load and bending moment is discussed. Various proposals for determining the amount and details of transverse reinforcement for seismic design are also reviewed.*

**Keywords:** axial load; bending moment; columns; concrete stress block; ductility; flexural strength; high-strength concrete; longitudinal reinforcement; seismic design; transverse reinforcement.

## CONTENTS

### CHAPTER 1—INTRODUCTION, p. 2

### CHAPTER 2—NOTATION AND DEFINITIONS, p. 2

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

### CHAPTER 3—EQUIVALENT RECTANGULAR CONCRETE STRESS BLOCK, p. 3

- 3.1—ACI 318-14 concrete stress block, p. 3
- 3.2—Other concrete stress blocks, p. 4
- 3.3—Performance of ACI concrete stress block, p. 6

### CHAPTER 4—TRANSVERSE REINFORCEMENT, p. 7

- 4.1—Constitutive models for confined concrete, p. 7
- 4.2—Previous research and general observations, p. 8
- 4.3—Equations for determining transverse reinforcement required in columns, p. 9
- 4.4—Definition of limiting drift ratio on basis of expected drift demand, p. 10

ACI Committee Reports, Guides, and Commentaries are intended to provide 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 441.1R-18 was adopted and published July 2018.

Copyright © 2018, 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.