

## **NEHRP Seismic Design Technical Brief No. 8**



# Seismic Design of Steel Special Concentrically Braced Frame Systems

A Guide for Practicing Engineers

Rafael Sabelli Charles W. Roeder Jerome F. Hajjar



#### NEHRP Seismic Design Technical Briefs

National Earthquake Hazards Reduction Program (NEHRP) Technical Briefs are published by the National Institute of Standards and Technology (NIST) as aids to the efficient transfer of NEHRP and other research into practice, thereby helping to reduce the nation's losses from earthquakes.

### NIST National Institute of Standards and Technology

NIST is a federal technology agency within the U.S. Department of Commerce that promotes U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life. It is the lead agency of the NEHRP. Dr. John (Jack) R. Hayes, Jr., is the Director of NEHRP within NIST's Engineering Laboratory (EL). Dr. John (Jay) L. Harris, III, managed the project to produce this Technical Brief for EL.

### **NEHRP Consultants Joint Venture**

This NIST-funded publication is one of the products of the work of the NEHRP Consultants Joint Venture carried out under Contract SB134107CQ0019, Task Order 12-335. The partners in the NEHRP Consultants Joint Venture are the Applied Technology Council (ATC) and the Consortium of Universities for Research in Earthquake Engineering (CUREE). The members of the Joint Venture Management Committee are James R. Harris, Robert Reitherman, Christopher Rojahn, and Andrew Whittaker, and the Program Manager is Jon A. Heintz.

#### **About The Authors**

Rafael Sabelli, P.E., S.E., is Director of Seismic Design at Walter P Moore, a structural and civil engineering firm with offices nationwide. He is a member of the American Institute of Steel Construction (AISC) Task Committee 9 – Seismic Provisions, AISC Seismic Design Manual Committee, the Building Seismic Safety Council's 2014 Provisions Update Committee (PUC), and the American Society of Civil Engineers (ASCE) Seismic Subcommittee for ASCE 7.

Charles W. Roeder, Ph.D., P.E., is a Professor of Civil Engineering at the University of Washington. He has performed extensive research on the seismic performance of steel and composite structures, and his research has focused on the seismic performance and rehabilitation of braced frames for the past several years. He is a member of AISC, Structural Engineering Institute (SEI), and Earthquake Engineering Research Institute (EERI), and serves on the ASCE 41 and AISC 358 standards committees. Jerome F. Hajjar, Ph.D., P.E., is a Professor and the Department Chair in the Department of Civil and Environmental Engineering at Northeastern University. He serves on the AISC Committee on Specifications and several of its task committees and is a member of the SEI Technical Activities Division Executive Committee. He is a fellow of ASCE and SEI and the winner of the 2010 Popular Mechanics Breakthrough Award, the 2005 AISC T. R. Higgins Lectureship Award, the 2004 AISC Special Achievement Award, and the 2000 ASCE Norman Medal. He is a registered professional engineer in Illinois and Minnesota.

#### About the Review Panel

The contributions of the three review panelists for this publication are gratefully acknowledged.

Michel Bruneau, Ph.D., P.E., is Professor in the Department of Civil, Structural, and Environmental Engineering at the University at Buffalo, the State University of New York, and an ASCE Fellow. He is a member of several AISC and Canadian Standards Association committees developing design specifications for bridges and buildings, and he served as Director of the Multidisciplinary Center for Earthquake Engineering Research. He has conducted extensive research on the design and behavior of steel structures subjected to earthquake and blast and has received many awards for his work. He has authored over 400 technical publications, including co-authoring the textbook *Ductile Design of Steel Structures* and three fiction books.

John A. Rolfes, P.E., S.E., is a Vice-President with Computerized Structural Design in Milwaukee, Wisconsin, a consulting engineering firm that provides structural engineering services throughout the United States. He is a member of the American Institute of Steel Construction Task Committee 9 – Seismic Provisions, AISC Seismic Design Manual Committee, AISC Industrial Buildings and Non-Building Structures Committee, and the Association of Iron and Steel Technology (AIST) Mill Buildings Committee.

C. Mark Saunders, P.E., S.E. is Senior Consultant and past President of Rutherford + Chekene Consulting Engineers in San Francisco and has been involved in seismic design and code development for more than 40 years. He has been a member of the AISC Task Committee 9 - Seismic Provisions, for more than 20 years and is currently its Vice Chair. He has served on the PUC for the NEHRP Provisions and is a past president of both the Structural Engineers Association of Northern California and ATC.



Applied Technology Council (ATC) 201 Redwood Shores Parkway - Suite 240 Redwood City, California 94065 (650) 595-1542 www.atcouncil.org email: atc@atcouncil.org



Consortium of Universities for Research in Earthquake Engineering (CUREE) 1301 South 46th Street - Building 420 Richmond, CA 94804 (510) 665-3529 www.curee.org email: curee@curee.org

# Seismic Design of Steel Special Concentrically Braced Frame Systems

## A Guide for Practicing Engineers

Prepared for

U.S. Department of Commerce National Institute of Standards and Technology Engineering Laboratory Gaithersburg, MD 20899-8600

By

Rafael Sabelli Walter P Moore

Charles W. Roeder University of Washington

Jerome F. Hajjar Northeastern University

July 2013



U.S. Department of Commerce Penny Pritzker, Secretary

National Institute of Standards and Technology Patrick D. Gallagher, Under Secretary of Commerce for Standards and Technology and Director

Contents   1. Introduction   2. The Use of Steel Special Concentrically Braced Frames   3. Principles for Design of Steel Special Concentrically Braced Frames   4. Analysis Guidance   5. Design Guidance   6. Additional Requirements   7. Detailing and Constructability   8. References   9. Notations and Abbreviations	2 3 10 14 23 25 27 29
9. Notations and Abbreviations 10. Credits	

#### Disclaimers

This Technical Brief was prepared for the Engineering Laboratory of the National Institute of Standards and Technology (NIST) under the National Earthquake Hazards Reduction Program (NEHRP) Earthquake Structural and Engineering Research Contract SB134107CQ0019, Task Order 12-335. The statements and conclusions contained herein are those of the authors and do not necessarily reflect the views and policies of NIST or the U.S. Government.

This report was produced by the NEHRP Consultants Joint Venture, a partnership of the Applied Technology Council (ATC) and the Consortium of Universities for Research in Earthquake Engineering (CUREE). While endeavoring to provide practical and accurate information, the NEHRP Consultants Joint Venture, the authors, and the reviewers assume no liability for, nor express or imply any warranty with regard to, the information contained herein. Users of the information contained in this report assume all liability arising from such use.

The policy of NIST is to use the International System of Units (metric units) in all of its publications. However, in North America in the construction and building materials industry, certain non-SI units are so widely used instead of SI units that it is more practical and less confusing to include measurement values for customary units only in this publication.

Cover photo – Entrance lobby of the Kirsch Center for Environmental Studies, De Anza College, Cupertino, CA.

#### How to Cite This Publication

Sabelli, Rafael, Roeder, Charles W., and Hajjar, Jerome F. (2013). "Seismic design of steel special concentrically braced frame systems: A guide for practicing engineers," *NEHRP Seismic Design Technical Brief No. 8*, produced by the NEHRP Consultants Joint Venture, a partnership of the Applied Technology Council and the Consortium of Universities for Research in Earthquake Engineering, for the National Institute of Standards and Technology, Gaithersburg, MD, NIST GCR 13-917-24.