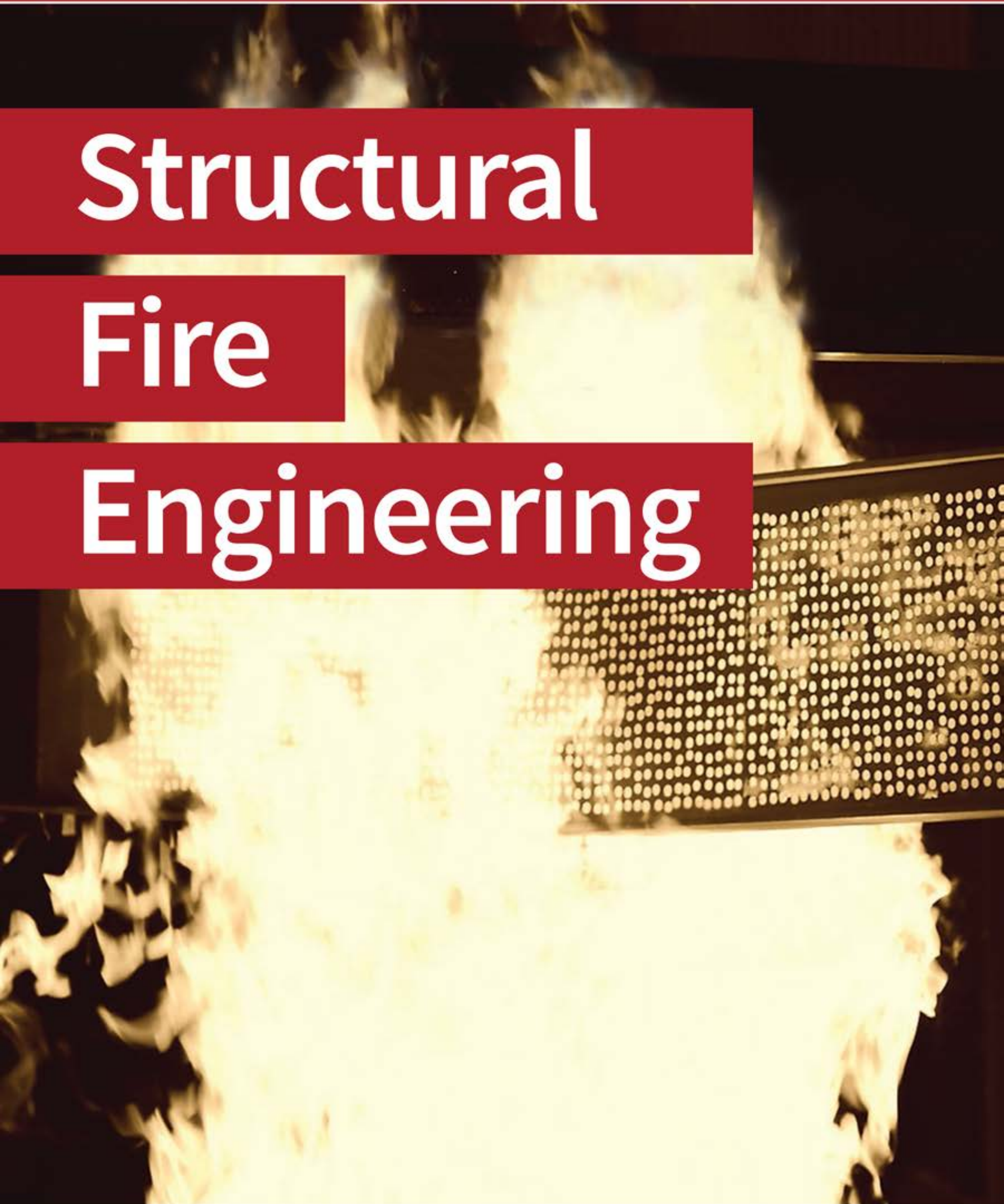
ASCE Manuals and Reports on Engineering Practice No. 138

# Structural Fire Engineering



Fire Protection Committee

Edited by Kevin J. LaMalva, P.E.

ASCE

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# Structural Fire Engineering

Prepared by the Fire Protection Committee of the Structures Engineering Institute of the American Society of Civil Engineers and Edited by Kevin J. LaMalva, P.E.

ASCE AMERICAN SOCIETY OF CIVIL ENGINEERS

SEI STRUCTURAL ENGINEERING INSTITUTE ASCE

Published by the American Society of Civil Engineers

**Library of Congress Cataloging-in-Publication Data**

Names: LaMalva, Kevin J., editor. | Structures Engineering Institute (American Society of Civil Engineers). Fire protection Committee, editor.
Title: Structural fire engineering / prepared by the Fire Protection Committee of the Structures Engineering Institute of the American Society of Civil Engineers; edited by Kevin J. LaMalva, P.E.
Description: Reston, Virginia: American Society of Civil Engineers, [2018] | Series: ASCE manuals and reports on engineering practice; no. 138 | Includes bibliographical references and index.
Identifiers: LCCN 2018024125 | ISBN 9780784415047 (hardcover: alk. paper) | ISBN 9780784481493 (pdf) | ISBN 9780784481714 (epub)
Subjects: LCSH: Building, Fireproof.
Classification: LCC TH1065 .S77 2018 | DDC 693.8/2—dc23
LC record available at https://lccn.loc.gov/2018024125

Published by American Society of Civil Engineers
1801 Alexander Bell Drive
Reston, Virginia 20191-4382
www.asce.org/bookstore | ascelibrary.org



***Errata:* Errata, if any, can be found at https://doi.org/10.1061/9780784415047.**


ISBN 978-0-7844-1504-7 (print)
ISBN 978-0-7844-8149-3 (PDF)
ISBN 978-0-7844-8171-4 (ePub)
Manufactured in the United States of America.

24 23 22 21 20 19 18 1 2 3 4 5

# MANUALS AND REPORTS ON ENGINEERING PRACTICE

(As developed by the ASCE Technical Procedures Committee, July 1930, and revised March 1935, February 1962, and April 1982)

A manual or report in this series consists of an orderly presentation of facts on a particular subject, supplemented by an analysis of limitations and applications of these facts. It contains information useful to the average engineer in his or her everyday work, rather than findings that may be useful only occasionally or rarely. It is not in any sense a "standard," however; nor is it so elementary or so conclusive as to provide a "rule of thumb" for nonengineers.

Furthermore, material in this series, in distinction from a paper (which expresses only one person's observations or opinions), is the work of a committee or group selected to assemble and express information on a specific topic. As often as practicable the committee is under the direction of one or more of the Technical Divisions and Councils, and the product evolved has been subjected to review by the Executive Committee of the Division or Council. As a step in the process of this review, proposed manuscripts are often brought before the members of the Technical Divisions and Councils for comment, which may serve as the basis for improvement. When published, each work shows the names of the committees by which it was compiled and indicates clearly the several processes through which it has passed in review, so that its merit may be definitely understood.

In February 1962 (and revised in April 1982), the Board of Direction voted to establish a series titled "Manuals and Reports on Engineering Practice," to include the Manuals published and authorized to date, future Manuals of Professional Practice, and Reports on Engineering Practice. All such Manual or Report material of the Society would have been refereed in a manner approved by the Board Committee on Publications and would be bound, with applicable discussion, in books similar to past Manuals. Numbering would be consecutive and would be a continuation of present Manual numbers. In some cases of joint committee reports, bypassing of Journal publications may be authorized.

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# CONTENTS

# PREFACE

Uncontrolled fire within a contemporary building is an extraordinary event that can have severe consequences. When structural systems are heated by fire, they experience thermal effects that are not contemplated by conventional structural engineering design. Since the early 20th century, building codes have primarily adopted standard fire resistance design. This design option is based on furnace testing of isolated structural components and relies almost exclusively on insulation for structural fire protection. Using this approach, designers select qualified assemblies from available listings to meet prescribed levels of fire resistance. As an alternative approach, structural fire engineering design explicitly evaluates the performance of structural systems under fire exposure, in a similar manner as other design loads are treated in structural engineering practice.

The 2016 edition of ASCE/SEI 7 (*Minimum Design Loads and Associated Criteria for Buildings and Other Structures*) includes a new Chapter 1, Section 1.3.7, "Fire Resistance." In addition to being the first time that fire resistance has ever been addressed in this standard, this section is intended to commence a new industry-consensus standard of care for structural fire protection. The default option is for the designer to strictly adhere to the requirements and restrictions of standard fire resistance design per the applicable building code without exception or extrapolation. As an alternative, ASCE/SEI 7-16 permits the designer to adopt a structural fire engineering approach as constituted in the standard's new Appendix E, "Performance-Based Design Procedures for Fire Effects on Structures." Notably, the inclusion of Appendix E in ASCE/SEI 7 marks the first time that fire effects are considered as an explicit design load in a U.S. structural engineering standard.

The main objective of the manual is to provide best practices when a structural fire engineering design approach is adopted, as permitted by ASCE/SEI 7 Chapter 1, Section 1.3.7, and as constituted in Appendix E. Because standard fire resistance design does not contemplate structural system performance or explicit performance objectives, there is no practical method for a designer to quantitatively compare the level of safety provided by a structural fire engineering design to that provided by a standard fire resistance design. Furthermore, it is not reasonable to require that a structural fire engineering design be "equivalent" to a standard fire resistance design, which does not provide any affirmative quantification of structural system performance under fire exposure. Hence, the best practices described in this manual for successful implementation of a structural fire engineering design are intended to stand independently from acceptance criteria in standard fire resistance design. Although the manual was written with the aim of providing best practices for engineers, it is hoped that it will also be useful to architects, building officials, and academics concerned with performance-based design for structural fire safety. Also, the combination of ASCE/SEI 7 Appendix E, this manual, and other related standards should advance structural fire engineering design as a distinct discipline within structural engineering.

Kevin J. LaMalva, P.E.
Structural Fire Engineer
Simpson Gumpertz & Heger Inc.

# ACKNOWLEDGMENTS

Contributions to the manual were received from consultants, professional researchers, and academic researchers. This manual has been prepared by the ASCE/SEI Fire Protection Committee, which included the following members at the time this manual was developed:

K. LaMalva, *Chair*
M. Garlock, *Past Chair*
F. Alfawakhiri
D. Banerjee
E. Beneberu
L. Bisby
N. Braxtan
M. Brightman
A. Carlton
D. Choe
S. Deeny
E. Fischer
J. Gales
J. Glassman
Q. Guo
E. Hantouche
R. Imani
A. Jeffers
E. Jensen
C. Jones
A. Jowsey
M. Ketabdar
M. Mahamid
H. Mahmoud
C. Maluk
T. McAllister
M. Morovat
K. Mueller
S. Quiel
H. Quiquero
M. Seif
S. Selamet
C. Smith
M. Smith
M. Soliman
R. Sun
S. Szoke
C. Zhang
A. Zhou

The following Committee Task Groups made major contributions to the manual:

Structural Analysis Task Group

Therese McAllister, *Co-Leader*
Spencer Quiel, *Co-Leader*
Matthew Brightman
Erica Fischer
Elie Hantouche
Reza Imani
Mustafa Mahamid
Hussam Mahmoud
Ruirui Sun

Mechanical Properties Task Group

Ann Jeffers, *Co-Leader*
Ali Morovat, *Co-Leader*
Farid Alfawakhiri
Dilip Banerjee
Eyosias Benebera
Qianru Guo
Alin Jensen
Mina Seif
Steven Szoke

Acceptance Criteria Task Group

John Gales, *Co-Leader*
Aixi Zhou, *Co-Leader*
Luke Bisby
Nicole Braxtan
Susan Deeny
Jonathan Glassman
Cristian Maluk
Hailey Quiquero
Serdar Selamet
Christopher Smith
Matthew Smith

The committee would like to thank Maria Garlock, who served as chair during the development of ASCE/SEI 7 Appendix E. Dr. Garlock's previous leadership of this committee deserves special acknowledgment.

The manual was reviewed by an ASCE/SEI Blue Ribbon Panel, consisting of the following members:

Lisa Choe
Richard Davis
Michael Engelhardt
Ramon Gilsanz
Nestor Iwankiw
Chris Jelenewicz
Venkatesh Kodur
Panagiotis Kotsovinos
Brian Kukay
Brian Meacham
Bernie Till
Jose Torero
Amit Varma

The contributions of the following individuals who are not committee members are appreciated:

Brad Douglas
Morgan Hurley
William Luecke
Hossein Mostafaei
Mohammed Sultan

The efforts of the following individuals who assisted the committee obtain permissions are appreciated:

Jillian Aberdale
Joan Cunningham
Michelle Howard

The cover image was captured at the National Fire Research Laboratory (NFRL) of the National Institute of Standards and Technology (NIST), where real-scale structural-fire testing is conducted to help advance structural fire engineering in the United States.

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# PART 1

# INTRODUCTION TO STRUCTURAL FIRE ENGINEERING DESIGN

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# CHAPTER 1
# INTRODUCTION AND KEY TERMINOLOGY

## 1.1 OVERVIEW

Heating and subsequent cooling of structural systems during fire exposure causes thermal load effects and nonlinear responses in structures, as well as temperature-dependent changes in material properties. Fire effects from restrained thermal expansion or contraction (if occurring) may result in significant loads and bending moments on members and connections. Reduced material stiffness and strength, and any other irreversible effects from fire exposure, may also result in large member deflections and deformations.

Fire protection of buildings may be achieved through the use of active and/or passive systems. Automatic fire sprinkler systems are commonly used for active fire protection. Fire sprinklers have demonstrated to be effective to control or extinguish fires during their early stages of growth approximately 85% to 90% of the time, where the fire was large enough to activate the sprinkler system and the sprinklers were present in the area of the fire (Ahrens 2017). Otherwise, fire sprinkler systems have failed to control the fire. The frequency of major building fires is relatively low because of (1) the small probability of ignition and the small probability of a fire reaching flashover, (2) occupant or fire department intervention, and/or (3) automatic sprinkler system control of the fire before it becomes fully developed. However, certain events (e.g., terrorism, arson, fires in multiple areas simultaneously, poor system maintenance, inadequate system design, building under construction, and so forth) may result in uncontrolled fires that are structurally significant. In these rare cases, the structural system may reach elevated temperatures for a significant time.