



Structural Fire Engineering



Fire Protection Committee
Edited by Kevin J. LaMalva, P.E.



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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.

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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.