Industry Efforts to Standardize the Treatment of SFP Variances

Kevin J. LaMalva, P.E.
FCIA’s Firestop Industry Conference
7 November 2019
Passionate Advocate for Building Fire Safety

  - Co-author: *ASCE/SEI 7-16 Appendix E*
  - Editor: *ASCE/SEI Manual of Practice: Structural Fire Engineering*
- ASCE/SEI 7 General Structural Requirements Committee
- ASCE/SEI Structural Design for Fire Conditions Standards Committee
- ASCE/SEI Technical Administrative Committee
- SFPE Fire Exposures to Structures Standards Committee
- SFPE Thermal Response of Structures Standards Committee
- NIST Full-Scale Structural Fire Testing Expert Panel
- SFPE New England Chapter, Past President
Outline

• Why Passive FP is **Under-Appreciated** by Stakeholders
• How Industry Practice **Should Be**
• How Industry Practice **Actually Is**
• How the Industry is **Changing**
Why Do We Thermally-Protect Buildings?

- Uncontrolled building fire is an *extraordinary event*
- Heating of structural systems causes thermal load effects
- Critical that adequate strength/stability is provided
### Why Do We Thermally-Protect Buildings?

**Percent of structure fires where sprinklers are effective**

<table>
<thead>
<tr>
<th>Number of Sprinklers Operating</th>
<th>All sprinklers</th>
<th>Wet pipe sprinklers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All structures</td>
<td>All structures</td>
</tr>
<tr>
<td>1</td>
<td>97%</td>
<td>98%</td>
</tr>
<tr>
<td>2</td>
<td>94%</td>
<td>96%</td>
</tr>
<tr>
<td>3 to 5</td>
<td>91%</td>
<td>93%</td>
</tr>
<tr>
<td>6 to 10</td>
<td>87%</td>
<td>86%</td>
</tr>
<tr>
<td>More than 10</td>
<td>79%</td>
<td>74%</td>
</tr>
</tbody>
</table>

"U.S. Experience with Sprinklers and Other Automatic Extinguishing Equipment" NFPA (2010)
The limit of safety is in some cases dependent upon temperature and in other cases upon expansion. The protection of the steel skeleton frame should, in all cases, be ample to prevent temperatures approximating to the safe limits.

Sanctioned Methods

• IBC recognizes the following methods:

  • A. **Individual FR listings** (usually product-specific)
    • *UL Directory*
  
  • B. **Prescriptive calculation methods/tables** (generic)
    • *IBC Sections 721 and 722*
  
  • C. **Equivalence**
    • *Per building authority approval*
A. Specify a Qualified Listing
B. Approved Empirical Calculation Methods

• W/D ratios (steel fire protection)
  • W: steel weight [lbf/ft.]
  • D: heated perimeter

• Steel W-shape columns protected with spray-applied fire resistive material (SFRM)

\[ R = \left[ C_1 \left( \frac{W}{D} \right) + C_2 \right] t \]

R: fire resistance [minutes]
t: thickness [in.]
C1 & C2: material-dependent constants
C. Demonstrating Equivalence (Qualitative)

• “Harmathy’s Rules”

Thermal resistance of multiple parallel layers exceeds the sum of the individual layers

Air gaps between layers increase the thermal resistance
C. Demonstrating Equivalence (Quantitative)

- Replicate test procedure analytically (less common)

SGH (2010)
IBC Section 703.3

703.3 Methods for determining fire resistance. The application of any of the methods listed in this section shall be based on the fire exposure and acceptance criteria specified in ASTM E119 or UL 263. The required fire resistance of a building element, component or assembly shall be permitted to be established by any of the following methods or procedures:

1. Fire-resistance designs documented in approved sources.

2. Prescriptive designs of fire-resistance-rated building elements, components or assemblies as prescribed in Section 721.

3. Calculations in accordance with Section 722.

4. Engineering analysis based on a comparison of building element, component or assemblies designs having fire-resistance ratings as determined by the test procedures set forth in ASTM E119 or UL 263.

5. Alternative protection methods as allowed by Section 104.11.

6. Fire-resistance designs certified by an approved agency.

Method A: Qualified Listings (Any Approved Source)

Method B: Approved Empirical Calculation Methods

Method C: Equivalence (In Context of Furnace Test)

Anything You Want? (Fire Consultants Pounce)
At this facility, the automatic sprinkler system suppresses the expected fires and lowers the temperatures. The resulting effect is that the integrity of the structural supporting steel is not compromised in the event of a fire. As such, the provision of a fire-resistance rating on the supporting structural steel through methods, such as applied fire-proofing, intumescent paint or drywall enclosures is not necessary.

By the way, here’s some pictures of a fancy fire model (irreverent, but was fun!).

Here’s your invoice. Thank you
Fire Modeling → “Arts & Crafts Play Time”
Fire Modeling → "Arts & Crafts Play Time"

Calculated exposed steel temperature along the W14x63 beam is 617°F at a point 10'6" from the fire source during the fire scenario.

Calculated exposed steel temperature along the W12x45 beam is 224°F at a point 10'6" from the fire source during the fire scenario.

Calculated exposed steel temperature along the W14x63 column, measured 10'6" above the adjacent floor surface is 750°F at a point 10'6" from a fire source during the fire scenario.

Elements directly above the Level 5 balcony walking surface are anticipated to be fireproofed and outside the scope of this exposed steel analysis.

FIRE SOURCE
2,000 kW

W24x55
(Part Level 5 Balcony)

W40x103
(Part Level 5 Balcony)

W14x63

Figure 18: Scenario 3 - Steel Temperature after 180 minutes of Fire Exposure

Time: 10770.6
The Business of Removing Passive FP

How Industry Practice Actually Is

Services

- Fire Protection Engineering & Design
  - Complete Automatic Sprinkler Design
  - Fire Pump Design
  - Prescriptive Fire Alarm Design
  - Performance Based Fire Alarm Design
  - Engineered Smoke Control System Design
  - Structural Fire Resistance Rating Analysis

Analysis and Consultation
- Building and Fire Code Analysis
- Preparation and Presentation of Code Variances and Equivalencies
- Accessibility (ADA/Disability) Compliance Consultation
- Existing Building Review and Analysis
- Life Safety Evaluations
- Crowd Manager Training
- Peer Review
- Third Party Plan Review
- Expert Witness
- Special Hazards System Analysis

Cutting Edge Computer Modeling
- Comprehensive Computer Fire Modeling for Smoke Control
- Comprehensive Computer Timed Egress Modeling
- Performance Based Design
- Peer Review

What defines our approach?

In a word: adaptability.

We know that no two projects are the same, and while we draw from our experience, we approach each client’s project with a fresh eye.

In another word: accessibility.

Whether on site or off, we are available to answer questions and address concerns.

Finally, affability.

We love what we do and it shows. We bring our collaborative spirit to bear on every project.

Clearly, our clients value these things. Over 95% of our business comes from word-of-mouth referrals.

Please contact us for client references and testimonials.

Learn More
Does this Happen in Structural Engineering?

• Geotechnical Engineer: “here’s the ground motions, all set right?”

• Structural Engineer: “wait….what’s the structural system?”

• Geotechnical Engineer: “not sure”

• Structural Engineer : “then how do we know it’s all set!?”
The “Uncertainty Trough”

- **Structural Engineers**
  
  Need to Understand Structural Fire Performance

- **Fire Consultants**
  
  Who Needs Applied Protection?

- **Concrete/Timber Industry**
  
  Is Steel Safe?

[Diagram showing the uncertainty trough with labels for each sector and questions.]

[Sociologists of Science and Technology]

How Industry Practice Actually Is
Conservatism Spectrum

Fire Consultants

“Restrained vs. Unrestrained”

Sprinkler “Trade-Off”

2018

4-hr Frame/No Variances

1-hr Frame/Easy Variances

2018

2-hr Frame

How Industry Practice Actually Is

4-hr Frame/No Variances

1-hr Frame/Easy Variances
Often-Abused IBC Section 703.3(5)

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→ Anything You Want? (Fire Consultants Pounce)
NIST Recommendation

NIST NCSTAR 1 (WTC Study)

• **Recommendation 9**: NIST recommends the development of *performance-based* standards and code provisions, as an *alternative* to current prescriptive design methods, to enable the design and retrofit of structures to resist real building fire conditions.

  • Affected National and International standards: *ASCE-7* [...]. The performance standards should be adopted as an alternative method in model building codes by mandatory reference to, or incorporation of, the latest edition of the standard.
IBC Provision 703.3(5)

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New Regulations

New Chapter 1 Section (Fire Resistance)

**Option 1**: Standard Fire Resistance Design
- Per requirements of the governing building code.

**Option 2**: Structural Fire Engineering
- Per requirements of *ASCE/SEI 7 Appendix E*.

“How the Industry is Changing”

“period”
Standard Fire Resistance Design


How the Industry is Changing
Structural Fire Engineering

- Control of a structural system’s heating (Demand)
  - Calculation of fire exposure and heat transfer
- Analysis/design of structural system endurance (Capacity)
  - Calculation of the structural system’s behavior under fire

There is no correlation between performance in a furnace test per its acceptance criteria and performance of a structural system under in-situ thermal conditions from uncontrolled fire exposure.
Separate Design Philosophies

• Structural performance: *Capacity > Demand*

<table>
<thead>
<tr>
<th>TABLE 1: CONTEMPLATION OF FIRE EFFECTS</th>
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<tr>
<td>Demand</td>
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<tr>
<td>Heating</td>
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<tr>
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<tr>
<td>Indeterminate*</td>
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<td></td>
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<tr>
<td>Standard fire resistance design</td>
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* Recognized by designers since the 1980s or perhaps earlier (Pettersson 1975, Law 1981)
New Regulations

ASCE/SEI Manual of Practice No. 138

Chapters 1-2: Introduction/Design Options

Chapter 3: Performance Objectives

Chapter 4: Fire Loading

Chapter 5: Material Thermal Properties

Chapter 6: Heat Transfer Calculation

Chapter 7: Structural Fire Effects

Chapter 8: Mechanical Material Properties

Chapter 9: Structural Analysis: Fire Effects

Chapter 10: Structural Acceptance Criteria
“Restrained vs. Unrestrained”

RECTIFICATION OF “RESTRAINED VS. UNRESTRAINED”

Kevin LaMalva 1, Luke Bisby 2, John Gales 3, Thomas Gernay 4, Elie Hantouche 5, Cliff Jones 6, Ali Morovat 7, Robert Solomon 8 & Jose Torero 9

Simpson Gumpertz & Heger Inc., USA, corresponding author 1
University of Edinburgh, UK 2
York University, CAN 3
Johns Hopkins University, USA 4
American University of Beirut, LBN 5
Facebook Inc., USA 6
University of Texas at Austin, USA 7
National Fire Protection Association, USA 8
University College London, UK 9

Keywords

Structural fire protection, restrained, unrestrained, thermal restraint, structural fire engineering, prescriptive method, standard fire resistance design.
10.5 TIMBER

Recently, project stakeholders in certain jurisdictions have advocated for the use of solid-sawn and engineered structural timber products for mid- to high-rise construction, which would not otherwise be allowed per SFRD. Moreover, there have been many recent research studies on the performance of timber structures under fire exposure. However, there is a very limited number of completed studies applicable to SFED. Hence, the development of definitive acceptance criteria for timber structures under fire exposure requires more research. This is particularly true for unprotected or exposed timber construction.
10.4 REINFORCED AND PRESTRESSED CONCRETE

Experimental studies conducted in the last few decades (Bailey 2002, Bisby et al. 2013, Yang et al. 2015, and Gales et al. 2016) have highlighted the need for more research on reinforced and prestressed concrete structural systems that is relevant to SFED. The commentary herein recommends specific research areas that could help establish definitive acceptance criteria for realistically restrained reinforced concrete structures at elevated temperatures.
7.3.4 Nonstructural Components

ASCE 7 Appendix E only applies to structural systems themselves and excludes consideration of other fire resistant assembly types including fire barriers, smoke barriers, firestop systems, and so forth (ASCE 2016). These excluded assemblies primarily serve to compartmentalize buildings during a fire event. In these cases, the mechanical integrity of the given assembly under fire exposure usually governs, as opposed to its structural response.
Restrict Bounds of Alternative Method

• **New Chapter 1 Section** (Fire Resistance)
  
  • Primary/secondary structural systems $\rightarrow$ **Option 1** or **Option 2**
    • Beams, girders, bracing, columns
  
  • Other fire resistant components $\rightarrow$ **Option 1 only**

Intumescent Fire-Resistive Materials (IFRM)—“Engineering Judgments” Usually Not Suitable
Restrict Bounds of Alternative Method

• Firestops, fire barriers, fire-rated joints, etc.

  Option 1 only
Restrict Bounds of Alternative Method

C 4.7 The method is limited to listed designs because thermal prediction methodologies inherently assume that the materials will remain in place during the fire exposure (mechanical integrity). Since mechanical integrity cannot be readily predicted, this standard relies upon furnace testing to assure that the materials are capable of remaining in place during the exposure. Listings define appropriate extrapolations from test conditions, such as application to heavier steel sections than tested. Use of fire resistant material thicknesses outside the range included in the listing cannot be done without full scale validation testing, as materials are often not as useful at thicknesses outside the range included in the testing. Examples would include a very thin cementitious material that may not maintain mechanical integrity or an intumescent material that will yield little or no additional benefit if a thicker layer is applied. These requirements do not preclude the use of analytical modeling to interpolate thermal performance between available furnace test result data.

If modifications to a listed fire resistance assembly are sought for constructability, economy, or other reasons, designers may elect to conduct analyses of such modifications as permitted by the alternative materials, design, and methods of construction provision in the building codes. If deemed acceptable to the enforcement official, analyses of this type are often used to demonstrate that the intent of the code has been met even though the assembly has been modified from that which was tested, and is therefore unlisted. For instance, a designer may analyze a case in which lightweight concrete is substituted for normal weight concrete for a given listed assembly without additional furnace testing. Although this type of approach is commonly employed in practice per the discretion of the enforcement official, this standard is not applicable to such analyses.
C8.3.3 Loss of mechanical integrity during the thermal exposure will invalidate the thermal prediction unless the particular form of loss of mechanical integrity is included within the model.
The Buck Stops Here

Prohibited per ASCE/SEI 7 and MOP No. 138

“Time-Equivalence Methodology”

- Compares realistic heating → heating in furnace
- Considers the thermal demand
- Neglects the structural system capacity
The Buck Stops Here

How the Industry is Changing
Expectations for a structural fire protection variance

To offer a path forward toward acceptance of a proposed structural fire protection solution, this section offers basic requirements for either the prescriptive method or the performance-based method, which are judged in a mutually exclusive manner per ASCE/SEI 7 (2016 Edition) Section 1.3.7.

If the performance-based method is selected, fire resistance qualification and/or equivalence calculations should not be used per ASCE/SEI 7 Sections 1.3.7 and E.2. Instead, the proposed fire protection solution should be analyzed on a system-level basis in the context of in situ thermal conditions per the requirements of ASCE/SEI 7 (2016 Edition) Appendix E, which includes the following integral procedural steps:
Expectations for a structural fire protection variance

If the prescriptive method is selected, the proposed fire protection solution must be analyzed on a component-by-component basis (i.e., individual beams, columns, floors, etc.) in the context of the standard fire test method. In this context, the simplest path to acceptance is to select UL-listed assemblies that are qualified for the required level of fire resistance per the NYCBC. Also, equivalence calculations (e.g., per ASCE/SEI 29) may be conducted to determine the level of fire resistance provided by generic assemblies. If neither of these approaches are sufficient to meet design objectives, the level of fire resistance may be quantified by simulating a standard fire test analytically per the approval of the building authority.
SFPE Core Competencies Standard (2019)

- Structural Fire Protection
  The objective of this topic is to provide knowledge regarding the impact of fire exposure on structural elements, using either the prescriptive compliance method or structural fire engineering.

Recommended Minimum Technical Core Competencies for the Practice of Fire Protection Engineering

The prescriptive compliance method relates to the qualification and prescription of structural fire protection as measured by the level of fire resistance, including the understanding of fire testing qualification, equivalence calculations per fire testing and its specific acceptance criteria, and explicit simulation of fire testing (if permissible). Structural fire engineering relates to the explicit design of structural systems to adequately endure thermal load effects from structural design fires based on specific performance objectives.

This alternative method requires participation by a structural engineer.
Fire events are rare. Fortunately, fire events are quite rare. Many buildings will never be exposed to a severe fire incident. Because of this, many faulty design concepts are never discovered, and the design concept is not really tested in a real fire scenario. Fires are not part of the day-to-day life of a building. Fire engineers who have developed faulty design concepts due to their lack of competence will most likely never be aware of it. This is not the case for other disciplines; faulty electrical systems, air-conditioning systems, structural designs, etc., are noticed quite soon.
How the Industry is Changing

Most would normally not expect (nor accept) that an electrical engineer is performing structural analysis or a structural engineer is performing mechanical ventilation design because they would normally lack the competence needed to perform technical analysis outside their discipline. Yet, when it comes to fire protection engineering, it seems anything goes. There is a misconception that you do not need to know the basics and that there is no need for a specific university education. Many consider learning on the job acceptable and sufficient; some even think you do not need an engineering background.

How would we feel about a structural engineer learning on the job, a medical doctor learning on the job, an architect learning on the job, or a psychologist learning on the job?

There is a definite need to create industry awareness. Increasing global
SFE Designs Requires Balance

How the Industry is Changing
With the manual approved for publication, likely this summer, LaMalva is on to other projects to elevate PBSFE. Spreading awareness of the new standard of care tops his list. This is important to LaMalva because it is related to curtailing improper intermingling of standard fire-resistance design—using code-prescriptive methods—and structural fire engineering to justify structural fire-protection variances. LaMalva says the variances allow the removal of fire protection from steel structures without proper structural analysis.
Kevin LaMalva to Lead Team to Advance Performance-Based Structural Fire Engineering

September 18, 2018

The Structural Engineering Institute of the American Society of Civil Engineers and the Charles Pankow Foundation are beginning a $230,000 research project intended to advance the use of performance-based structural fire engineering.

The adoption of SFE in the U.S. is hindered by a lack of participation by structural engineers, a lack of trial designs demonstrating the potential benefits to stakeholders and a lack of familiarity with the approach by building officials, says SEI.

The research, led by structural and fire protection engineer Kevin LaMalva of Simpson Gumpertz & Heger, is intended to support the development of procedural guidance to execute an SFE design, in accordance with the new ASCE/SEI 7-16 Appendix E industry standard.

The project will employ a scientific and engineering approach to quantify the fire exposure and structural behavior of existing building designs during fire. The final document, expected by the end of October 2019, will be free for all to use.
Industry Response (2019)

PROJECT

Advancing Performance-Based Structural Fire Engineering Design in the U.S. through Exemplar Procedural Guidance

Research Purpose | The Structural Engineering Institute (SEI) of ASCE is pursuing, as part of its Vision, the advancement of performance-based design. Advancing the adoption of performance-based structural fire engineering (SFE) within the AEC industry will benefit public safety while delivering more efficient and economic building designs. However, the adoption of SFE in the U.S.

Grantee | American Society of Civil Engineers/Structural Engineering Institute

Project Area | Structural Engineering

CPF Research Grant # | 04-18

Award Amount | 230,000

Grant Period | Sep 1, 2018 - Oct 31, 2019

Grant Status | In Progress

Principal Investigator | Kevin LaMalva, Simpson Gumpertz & Heger

Industry Champions | Larry Griffis, Walter P. Moore
Najib Abboud, Thornton Tomasetti
Ron Klemencic, Magnusson Klemencic Associates
Industry Response (2019)

• NIST Structural Fire Performance Test Facility

Source: National Institute of Standard and Technology
IBC Proposal (Pending)

  - Very tall buildings > 420 ft.

**Prescriptive method:** primary structural frame shall have minimum **4 hour fire resistance**.

**Alternative method:** structural fire engineering analysis per ASCE/SEI 7-16 Appendix E considering the **nominal level of fire resistance** per IBC Table 601 and subject to building authority approval.
Conservatism Spectrum *(Need Your Support)*

- **ASCE/SEI 7-16**
- **ASCE/SEI MOP No. 138**
- **Structural Engineers**
- **Building Authorities**
- **Firestop Contractors International Association (FCIA)**

**2022**
- 4-hr Frame/ No Variances
- 2/3-hr Frame/ Appendix E Only

**2019**
- 1-hr Frame/ Easy Variances

*How the Industry is Changing*

SIMPSON GUMPERTZ & HEGER
What Can You Do Right Now?

- Advocate for 3rd-party review of Passive FP variances
  - It should not be a “walk in the park” for the proposing (fire consultant)

- Continue industry reform/regulation efforts
What Makes Performance-Based Design Viable?

1. Trust
2. Conservatism
3. Credibility
Thank You For Your Consideration

Questions (Now or Anytime)?  →  kjlamalva@sgh.com

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