Fire Protection Performance Evaluation for Historic Buildings

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ABSTRACT: In many respects, historic buildings have long been under-served by the fire safety engineering community and have not received the level of consideration warranted structures of significance and distinction. This can in part be explained by the idiosyncratic nature of these buildings that defy standard code and construction approaches given their archaic configurations and materials. This paper reviews current activity to address these issues including a comprehensive review of fire safety codes in the U.S. This review identified many disparate approaches to regulating fire safety in historic buildings. There are different administrative and technical components and different administrative and technical approaches. The 2001 edition of NFPA 914, *Code for Fire Protection in Historic Structures*, focuses on performance-based evaluation as an important alternative to prescriptive codes. Goals, objectives, and performance criteria are essential elements of the new code. This paper is adapted from a presentation at the Third International Conference on Performance-Based Codes and Fire Safety Design Methods [1].

KEY WORDS: fire safety, fire protection, heritage preservation, historic buildings, NFPA 914, performance evaluation.

FIRE SAFETY FOR HISTORIC BUILDINGS

"CONSERVATION OF CULTURAL Heritage" is a stated goal of the ISO Technical Committee on Fire Safety Engineering [2]. Most societies recognize that the work of previous generations is an important part of their culture. Historic buildings are a valuable part of this environment. They have a special place in society and are appreciated and enjoyed. Their age, history, appearance, materials, and craftsmanship all combine to make each one a unique, non-renewable resource [3]. The number of listed or designated historic buildings is unknown. In Europe, there are millions. In the U.S., any building over fifty years old is eligible for historic status.

Historic buildings are exposed to the same fire threats as other buildings, including arson, lightning, construction operations, faulty equipment and inadequate

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maintenance. Many specific aspects of the fire problem are unknown because, statistically, historic buildings are almost invisible. Fire loss data is typically collected only on factors that relate to fire cause and origin. There is usually no fire loss data by historic significance or even building age. The way we know about fire losses of historic buildings is by observing those that occur around us or from media attention to those that are of such importance that they are newsworthy, for example, Windsor Castle [4,5]. A notable exception is in Sweden as reported by Kippes and Homberg [6].

Preserving our heritage from fire is a topic that is currently being addressed around the world, but especially in Europe. The CIB W014 Working Commission identified seven projects of highest priority for the 2001 CIB World Congress in New Zealand. One of these projects is a "guidance document on rational fire safety engineering approach to fire safety in historic buildings" [7]. This represents ongoing work that was initiated some ten years earlier [8]. A Conference on Fire Protection and the Built Heritage was held in Edinburgh in 1998 [9] and the Third International Symposium on Fire Protection of Heritage was held 6–9 October 1999 in Poland [10]. The International Conference on Fire Protection of Cultural Heritage was held in Thessaloniki, Greece in June 2000 [11]. The proceedings of these conferences contain many examples of the dilemmas in providing fire safety for historic buildings and the problems faced and handled by performance-based fire safety evaluation. Other examples of heritage fire protection approaches have been published in recent articles in *Fire Protection Engineering* [12–14].

Fire Safety Codes

In addition to loss by fire, historic buildings are also vulnerable to another type of destruction—that caused by a lack of understanding of how design professionals should deal with the unique configurations and performance characteristics. Standard fire protection approaches, based on ideal (new construction) conditions that drastically differ from the conditions presented by historic buildings, can have adverse impacts on historic materials and spaces and destroy the very materials or qualities that give the space its historic character. These damaging approaches include removal of significant architectural features, and changes made for the installation of fire protection equipment. The problem is not in the introduction of these changes, but in their implementation without sensitivity and understanding of how each change affects the historic character of the building.

While building codes have progressed to keep up with developing techniques of modern construction, the issues of fire safety for historic premises have been primarily relegated to guidance documents with no legal authority, e.g., References [3,15]. A few rehabilitation codes have evolved that recognize the inherent differences between new construction and existing buildings, but, there is concern that they have retained the inflexibility and additional problems of specification-based codes [16]. They are usually inadequate in their approach to historic buildings, the subcategory of existing buildings with the highest requirement for property protection. None of the recent generation of codes has resolved the conflict between the prescriptive language of fire safety and the philosophical language of the *Burra* [17] and *Venice* [18] *Charters*, or the U.S. *Secretary of the Interior's Standards for the Treatment of Historic Properties* [19], documents used internationally and in the United States to identify appropriate preservation approaches and techniques.

A recent study has examined in detail fifteen different U.S. model and state codes that are presently applied to historic buildings [20]. The intent of this analysis was to identify the regulatory methodologies and component parts of codes that are presently applied to historic buildings. It was anticipated that this would then allow the synthesis of a comprehensive and systematic code for historic buildings. The codes were first analyzed by identifying specific common and unique components. Then they were examined for the basic approaches employed. These are two separate taxonomies of the information that comprises concepts within the codes reviewed, components and approaches.

Components are the chapters or principal sections of a historic building code. These were further divided into technical components and administrative components. A technical component is a chapter or principal section of a historic building code that deals with a specific area of technical expertise. The technical components identified in the codes reviewed are shown in Table 1.

Administrative components are code sections that usually appear in the first chapter or chapters. They typically deal with implementation and special cases such as shown in Table 2.

Approaches are methods for considering a similar set of building and fire safety attributes or technical details to achieve code objectives. They are the various ways of treating the interaction of attributes that define each technical component within the framework of the administrative components. Six such approaches were identified among the fifteen codes reviewed. They are listed in Table 3.

As with the components, it was found that these approaches could also be divided into two groups based on whether they were primarily administrative or technical. The first three approaches, consultation, hazard ranking and proportionality, are most often used in an administrative context. The other three approaches, adapting prescriptive requirements, indexing and performance-based evaluation, are more exclusive options for systematically evaluating the technical attributes of a building. Each of these groups will be discussed separately.

Administrative Approaches

The administrative approaches, consultation, hazard ranking, and proportionality are used by some codes individually and by others jointly. Consultation is a form of negotiation between a code official and a historic preservation official to

Table 1. Technical components of historic building codes.

Building and Fire Safety
Accessibility
Electrical
Energy Conservation
Mechanical
Plumbing
Structural/Seismic

Table 2. Administrative components of historic building codes.

Appeals/Variances
Archaic Materials and Methods of Construction
Change of Occupancy
Definitions
Documentation
Historic Museums/Sites
Relationship to Prevailing Code(s)
Unsafe Buildings
Relocation of Buildings

Table 3. Approaches to evaluating building attributes.

Consultation
Hazard Ranking
Proportionality
Adapting Prescriptive Requirements
Indexing
Performance-Based Evaluation

reach a consensus on either a general approach to evaluation or on a specific building attribute. This has also been recognized as an integral component of performance-based fire safety design.

Hazard ranking is an ordering of fire hazard based on occupancy classification. An existing building may change to an occupancy in the same or lesser hazard category by complying with the provisions for existing buildings. If a change of occupancy is to a higher category, the requirements for new construction in the prevailing building code apply.

Proportionality refers to a variation of requirements based on type or extent of work to be performed. The concept of proportionality in the codes reviewed is primarily used as a trigger to identify when a historic building must conform to a code or the amount of code compliance required or number of provisions that are applicable.

Technical Approaches

The three technical approaches, adapting prescriptive requirements, indexing and performance-based evaluation, are more exclusive options for systematically evaluating the technical attributes of a building. Adapting prescriptive requirements refers to variations of prescriptive requirements in the prevailing code that may be acceptable for historic buildings. In the codes reviewed, this is achieved by one of three principal means; identifying alternatives to code provisions, establishing ways of asserting equivalency to code provisions, or modifying code provisions for historic buildings. While adapting existing requirements can help avoid destruction of historic fabric in providing an acceptable level of life safety, it typically does not address property protection objectives of cultural conservation.

Indexing is a form of multi-attribute decision analysis that produces an accumulated score of positive and negative system attributes contributing to the overall objective of an area of concern. For example, the wind-chill factor accounts for both wind speed and temperature to describe how cold it feels. In risk analysis, multi-attribute evaluation is usually referred to as risk indexing [21,22]. Fire risk indexing has been used for existing buildings for the last three decades and has recently been applied to a class of historic buildings [23].

PERFORMANCE-BASED EVALUATION

Performance-based evaluation offers a logical and systematic approach to assessment of fire safety in historic properties. Code compliance is achieved by showing, through use of appropriate evaluation methods, that a proposed fire safety plan will meet specified objectives. Documented procedures for performance-based fire safety have evolved as engineering guidelines [24–26]. These

Table 4. Performance-based approach.

Goals
Objectives
Performance Criteria
Fire Scenarios
Evaluation

procedures and their use have been described in many venues including the proceedings of the International Conferences on Performance-Based Codes and Fire Safety Design Methods [27–29]. In general, the essential elements of a performance-based approach are those listed in Table 4.

In a performance-based evaluation, fire safety goals and objectives are translated into performance criteria. Fire models and other calculation methods are then used in combination with the building design specifications, specified fire scenarios, and explicit assumptions, to calculate whether the performance criteria are met. If the criteria are met, then compliance has been achieved.

Performance-Based Fire Safety for Historic Buildings

Performance-based fire safety has the most impact when there is conflict with traditional fire safety measures imposed by regulations. Fire safety in historic properties is one such area. The National Fire Protection Association (NFPA), Technical Committee on Protection of Cultural Resources recently revised their guide document, NFPA 914, into a code for protection of historic structures from fire [30, 31]. With respect to the performance-based approach, this code closely follows the performance-based option in the NFPA *Life Safety Code* [32–34]. Significant features of the performance-based approach in these documents include goals and objectives, and criteria for performance-based evaluation.

Explicit statements of goals and objectives are the first need for developing a performance-based approach to fire safety evaluation. This step is necessary as a means to generate ideas for creating alternatives and, most important, to provide a basis for the evaluation of alternatives. Goals are statements that describe the aspirations of an organization or of society. They develop as generalities without regard for specific implementation. The cost or means of achievement is not considered. In this sense, goals are idealistic; they do not reflect existing resources or technology. They represent the general end toward which some effort is directed. The goals and objectives of NFPA 914 are cited here as examples.

Historic Preservation Goals

In historic preservation, the overall fire safety goal is to preserve cultural heritage (art, artifacts, and historic structures) from fire and fire protection measures. More specific objectives include limiting impact of fire to a recoverable level of damage, providing that distinguishing original qualities or character of the building are not irreversibly altered to provide fire safety, and preventing permanent damage to artifacts from adverse effects of fire suppression, accidental discharge, or leakage. Life safety, property protection and operational continuity take on different proportions when preservation of the building in its original form is a transcending management goal. Historic significance is a marked but immeasurable value to be protected. Its loss to fire is forever and there can be no replacement. At the same time, the means for protection cannot so intrude on authenticity as to destroy the value being protected. Traditionally, specified levels of hazard or protection do not correlate with the goal of protecting our heritage. While the protection of life, property and mission are important, the intangible value of our heritage at risk may outweigh these purposes. Thus, historic preservation is necessarily an additional goal of fire safety.

The goals in NFPA 914, *Code for Fire Protection in Historic Structures*, are prefaced with the following:

> The goals of this Code shall be to provide fire protection to all historic structures and their occupants while protecting those elements, spaces, and features that make them historically or architecturally significant. The two goals shall be to: Provide protection and life safety from the effects of fire and to maintain the historic fabric and integrity of the building. The goals of this code shall be accomplished by operational approaches, system approaches, or the consideration of other factors.

The stated goals include both life safety and historic preservation. For life safety the goals are:

> The life safety goal of this Code is to provide an environment safe from death or injury in fire and similar emergencies by: a) Protecting occupants not intimate with the initial fire development, and b) Improving the survivability of occupants intimate with the initial fire development.

For historic preservation, there is a three-part goal:

> The historic preservation goal of this code is to provide protection against damage to and loss of historic structures, their unique characteristics, and their contents by: a) Protecting against the loss of and damage to historic structures or materials from fire or fire suppression efforts, b) maintaining and preserving original space configurations of historic buildings, and c) Providing alternatives to minimize the alteration, destruction, or loss of historic fabric or design.

The term "historic fabric" is defined as original or added building construction materials, features and finishes that existed during the period deemed to be most architecturally or historically significant.

Fire Safety Objectives

To establish a policy for achieving goals, objectives must be defined. Objectives are the specific results by which goals are fulfilled. Whereas goals are subjective and difficult to measure, objectives are more absolute and determinable. Desired goals or aspirations can be stated easily, however, specifying objectives or targets that one has a reasonable hope of attaining and assigning priorities to may take considerable thought and even research. Restrictions such as the need for preserving the character of historic buildings with sensitivity, awareness and appreciation of significant features must be quantitatively formulated.

The stated fire safety objectives in NFPA 914, *Code for Fire Protection in Historic Structures*, also apply to both life safety and historic preservation. For life safety there are three stated objectives:

> An egress system shall be designed, implemented, and maintained to protect the occupants not intimate with the initial fire development for the time needed to evacuate, relocate, or defend in place.
>
> Structural integrity during a fire shall be maintained for the time needed to evacuate, relocate, or defend in place the occupants not intimate with the initial fire development.
>
> Systems, building characteristics, or occupant characteristics utilized to achieve the goals shall be effective, maintained and operational.

For historic preservation there are five objectives listed in the Code:

> Fire safety and fire protection features shall be designed, approved, implemented, and maintained so as to preserve the original qualities or character of a building, structure, site, or environment.
>
> Removal or alteration of any historic material or distinctive architectural feature shall be minimized.
>
> Distinctive stylistic features or examples of skilled craftsmanship that characterize a building, structure, or site, shall be treated with sensitivity.
>
> A compatible use for a property that requires minimal alteration of the building, structure, or site and its environment shall be encouraged.
>
> New additions or alterations shall be designed and constructed in such a manner that, if such additions or alternations were to be removed in the future, the essential form and integrity of the structure would be, to the greatest degree possible, unimpaired.

The above objectives relate to those commonly addressed in the rehabilitation of historic buildings.

Performance Criteria

The performance-based approach is one of establishing fire safety objectives and leaving the means for achieving objectives to the design professional. To carry out such an arrangement, we need the capability to decide whether fire safety objectives are being met. This requires the establishment of an acceptable level of performance. Criteria for performance-based evaluation are threshold values by which achievement of measurable objectives are evaluated. Due to the subjective nature of many aspects of cultural heritage, such criteria may not always be definitive, for example, how do we measure the aesthetic intrusion of fire safety systems on distinctive stylistic features? and what qualities define the skilled craftsmanship that characterize a historic building?

An acceptable level of performance is a performance criterion framed or formulated so that it identifies a measurable level of success in achieving fire safety objectives. In order to measure performance, it is necessary to have a measurement scale. The scale of historic value has no endpoint; hence we need to deal with terms such as "priceless" and "irreplaceable." Preservationists and conservators have been loath to associate a replacement value with historic buildings. Yet, mechanisms and techniques for classifying historic value do exist and are being used. For example, the A, B, C, grading of "listed" buildings in the UK is one way to rank importance of historic property. The Building and Fire Research Laboratory at NIST has developed a tool for evaluating relative historic importance of documented structures [35]. It is a numerical rating scheme that assesses historic significance of buildings, zones within buildings and architectural elements within zones. A much simpler approach to heritage grading of architectural artifacts is to classify elements as irreplaceable, replaceable, reproducible, or expendable [36].

Specific performance criterion for archaic structural materials in the form of fire resistance ratings is summarized in the *Guideline on Fire Ratings of Archaic Materials and Assemblies* [37], which is reproduced as Annex D of NFPA 914. Additional criteria are included in the section on historic and cultural facilities in the *SFPE Engineering Guide to Design Performance Criteria* [38].

Non-Thermal Fire Damage

An important aspect of fire loss in historic properties is nonthermal fire damage. In some fires, the building and contents are seriously damaged by direct fire exposure. For other fires, the damage is indirect, caused by the nonthermal effects that are especially destructive to sensitive materials in museum collections such as paper and textiles. Nonthermal fire damage is produced by smoke and corrosive gases generated in a fire.

Fabrics, artwork, and many finishes are especially susceptible to soot deposition and corrosivity of fire gases in the presence and absence of fire extinguishing agents. Because of the large area over which nonthermal products of combustion are spread in a fire, there can be damage to many more documents and artifacts than that caused by heat and flames. Even in the best outcomes, extensive cleanup and recovery operations are required.

Design Fire Scenarios and Performance Evaluation

A scenario is a sequence of events that includes initiating events and their consequences. The initiating events of a fire scenario provide the fire challenge or "load" against which one determines whether the performance criteria are met. Fire models and other calculation methods are used to determine whether the building design will achieve the performance criteria, given each set of initiating events. Appropriate fire scenarios will cover the severity of loss or historic value at risk and the potential for harm from products of combustion, including nonthermal fire damage. Performance evaluation consists of comparing predicted outcomes with the stated objectives. An acceptable performance-based fire safety design is one that satisfies some specified performance evaluation.

Performance-based fire safety is one way to address the conflict in historic properties of achieving life safety without building modifications that intrude on historical integrity. However, it does not represent a panacea. Ideally, there should be a choice among modifications of prescriptive requirements, fire risk indexing and performance-based evaluation.

SUMMARY

Historic buildings pose unique fire safety engineering problems. Most significant is that such buildings do not conform to the generic types of ideal new construction on which building codes and fire protection applications are based. A historic structure represents an artifact or visual record of architectural or historical significance. If the building is destroyed, this function ceases. Creative solutions must be developed that meet fire and life safety objectives without compromising the historic or architectural significance of the historic building. A first generation of performance codes for fire safety of historic buildings is evolving that may contribute solutions to these problems. Fire safety in historic properties is a unique worldwide problem with little guidance for scientific solutions and it is a problem of increasing relevance as the buildings in our world become older and of greater historical importance. Performance codes will provide an opportunity to target a fire safety approach to each building's idiosyncratic characteristics. The increasing ability to predict fire hazard and performance accurately and to provide a quantifiable basis for the acceptance of equivalent systems will ease the inherent conflict between building codes and traditional approaches to fire safety for historic properties.

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