AN OVERVIEW OF FIRE PROTECTION IN HISTORIC BUILDINGS

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Abstract

Fire was one of the most serious threats for the buildings and sites through the centuries. This threat is omnipresent and results irreplaceable losses. During the last decades, among various countries authorities, fire experts, conservationists and citizens a great concern on the conservation of cultural heritage including fire protection has been arisen. In this paper a global international review about the state of the art of this important matter is given. It is defined briefly the main terms and the philosophy of conservation, the principles of the fire safety design both in the prescriptive and in the modern fire safety engineering approach. Information about significant fires in historic buildings and sites, as well on several related international activities of different organizations and bodies is quoted. Finally a summary of two research activities in Europe is described.

Historic Buildings and sites

General

During the recent decades and especially since the seventies a great concern about the Conservation and Preservation of Cultural Heritage has appeared in many countries. This universal concern has different reasons, among them the fact that many historic monuments are being rapidly destroyed due an anarchic speculating urban development, which places the man in the margin of social life giving priorities to the “market laws”. On the other hand, with the postmodern movement of environmental protection, the concern on monuments preservation passed from a group of experts to a wide circle of the public. [1]

The protection of monuments is scooping to the preservation of historic and cultural heritage and to the transmission from one generation to the next, in order to keep the cultural identity and continuity of the nations and the people through the centuries. The historic memory of a nation is often based on its technical, political and cultural achievements and creations of the past.

The willing for perpetuity comes from the consciousness of the unavoidable fact of death and the unreturnable current of the time. Man pursues after death glory and fame thinking that it is a way to beat the disappearance and to assure immortality. The replacement of the buildings with new ones is considered as a natural and reasonable historic evolution by the time running. However, many times this replacement took place unbalanced and in non-normal conditions, so that the regular succession between the past and the future has been disordered.

An event symbolized by the erection of a monument does not always assure its maintenance through the time. It often depends on the consideration given by the future societies in which degree they can evaluate cultural values and on the other
hand, how far the creations and the values can resist time. Every society and every season have various criteria for the value and the necessity of monuments conservation. There are cases in the past, when nations destroyed the monuments of other conquered countries in order to exterminate the symbols and to eliminate their national conscience and cultural identity.

The justification for preservation is made economically easier and logically reliable if the restored building is capable of beneficial and profitable use. Present day use brings often the necessity of satisfying present-day standards and codes both for the occupants of and the visitors to the historic buildings.

Definitions

Speaking about conservation of historic buildings and sites we must use a common language, which has been established by the conservationists during many years and is written in several international texts (Conventions, Agreements etc.)

In the Charter of Venice (1964) the definition of the historic monument does not cover only the architectural creature, but many times an urban or rural area as an evidence of a historic event or a specific civilization. It does not refer only in aesthetically famous creations, but also in modest anonymous works which gained through the time an important cultural value. [2] Conservation is defined as the technical intervention to protect a historic monument or a traditional or listed building from dilapidation and to restore it.

The main characteristics of a monument are considered the following:

- **Originality or innovation**, which refers to the special value of every monument, that could not be repeated even in the case of a precise copy, since it includes a correlation of those components and parameters consisting an original creation.
- **Time (historicity)**, which includes all time phases and interventions to the monument, giving the chronological sequence of events in the life of the creature.
- **Quality**, which is difficult to be defined because the elected evaluation system is several times subjective depending on the ideology and the aesthetic criteria of every society and each period.
- That was the reason why a fourth criterion that of the symbolism was added, in order to declare the message from the past contained in the monument and is expressed with each accurate form.

In the meeting of 21 member-states of European Council in Granada of Spain (1985) dilated meanings of monument, architectural complex and historic site were established. It was agreed that these terms include not only archaeological and artistic masterpieces or significant historical heirlooms, but also buildings, complexes or areas with a special scientific, social or technological interest.

**Categorization of historic buildings**

From the point of view of fire safety the categorization of historic buildings in a fire system evaluation is needed. Categories of historic construction and fire safety evaluation must be used to assess the inherent fire risk and the need of architectural
and cultural sensitivity in order to apply either modern fire codes or any available alternative approaches.

Historic monuments could be categorized according to:
- occupancy
- building type
- risk
- cultural contents
- cultural value

**Occupancy** is the use or the intended use of a structure, in terms of number of people present and whether or not modern or historic functional processes are being performed.

**Building type** refers to the nature of historic construction as the size of the building, the nature of fabric etc.

A basic level of **risk** is inherent in all historic structures and any loss would be harmful. In the process of fire risk analysis four major steps can be identified:
- hazard identification
- risk estimation
- risk evaluation and
- risk reduction

This approach could give another way of historic buildings categorization.

The **contents** of an historic building typically reflect modern occupancy. Building Codes classifies and regulates the hazard of contents. Categories of historic buildings identify modern and historic contents.

**Cultural values** may be archaeological, architectural, historic, functional, scientific, art, symbolic etc. In many cases they represent only part of a building. It could be structures irreplaceable or the contents only irreplaceable. It may be both structure and its contents of historic importance.

Although historic buildings represent a very small proportion in the total number of buildings, they consist of a wide range including castles, palaces, churches, ancient and some prehistoric monuments, as well as museums, libraries, traditional buildings and historic city and other settlements etc. On the other hand, there are significant historic contents inside either historic or modern buildings like icons, frescos, manuscripts, paintings, statues etc. Some of these cases are shown in the following pictures.

![The keep of Himeji Castle (Japan)](image)

**Fig. 1**  The keep of Himeji Castle (Japan)
Fire safety in historic buildings

Monumental fires
Most of the historic built-environment has been destroyed from various reasons, as mentioned above, and it is time to preserve any of the humanity cultural heritage remained to remind us the past and the history.
Although most of historic buildings have built in periods when very poor, if not at all, Fire Codes and Standards were applied, many of them exist now in their original condition after such a long time. This happened because, on one hand the traditional builders and architects applied several sophisticated fire protection measures based on the state of the art at that time as well on common sense and on the other hand, after major fires and conflagrations the authorities put in force more severe and more developed fire protection legislation.

We shall refer below to some of the so called “monumental fires” in historic structures, which had an international importance:
The fires of the wooden wall and of many temples of the Athenian Acropolis by the Persians (480 B.C.-Herodotus, III 52). After this complete destruction of the first Parthenon, Athenians built the new Periclean Parthenon which, although heavily damaged through the centuries, survives up to now. Two large fires destroyed most of the valuable parts of the monument. The first one was put by the strange Celtic tribe of Eruls pyromaniacs on the year 267 A.D. The second fire was due to the Venetian F. Morozini (1687 A.D.), who bombed the temple of Parthenon completing the destruction of the Celts [5].
City of ancient Rome (Galatians 387 B.C.)- (Nero 64 A.D.)
Library of Alexandria (Julius Cesar 47 B.C.-Aurelianus 270 A.D.-Serapeion 391 A.D. and Kalif Omar 641 A.D.)
- Churches destroyed by fire during recent years:
  Hōryū-ji temple, Nara Japan (7th A.D century), 1949
  Kevlar Germany (15th century)
  York Minster UK (15th century), July 1984
  Luxemburg (15th century)
  Klein-Krotzenburg Germany (15th century)
  Bielefeld Germany (19th century)
  Münster of Freiburg Germany (13th century)
  Dom of Berlin (18th century) Germany
  Monastery of Simonopetra Greece (14th century), August 1990
  Christianborg Palace Church, Copenhagen, Denmark, June 1992
  St George’s Church, Halifax, Canada, June 1994
- Castles/palaces:
  Philipplsruhe Hanau, Germany
  Hampton Court Palace, England, March 1986
  Purschenstein Neuhausen, Switzerland
  Redoutensal Hofburg Palace, Vienna Austria , November 1992
  Windsor Castle, England, November 1992
  Pont de la Chapelle, Lucerne, Switzerland, August 1993
- Cities:
  London Great Fire (1666) was the initiator of building regulations in England. The easterly wind assisted the fire spread and highlighted the need of buildings separation and the control of their walls and roofs ignitability.
  Jamestown, Virginia USA (1608)
  Plymouth, Mass. USA (1623)
  Manhattan New York, USA (1628)
  Edinburgh Great Fire (1824)
  Chicago, USA (1871)
  Aalesund, Norway (1904)
Objectives
Although fire safety objectives have been expressed in different ways by different authorities in different countries, generally there are accepted two main aspects of fire protection for modern buildings: life safety and property protection. For historic buildings it must be added the protection of cultural values either for the buildings or for their contents. It is not possible to achieve an absolute fire safety. In most cases, a
proper fire safety design assume that a limited unwanted fires will occur and means shall be provided to minimize the losses from fire till an acceptable level.

**Measures**
The main safety measures in connection with the above mentioned objectives are the following:
Reducing the causes of fire incidence
Providing means of escape for the occupants and the visitors of the buildings
Preventing rapid growth of fire
Preventing internal fire spread
Preventing external fire spread
Controlling and extinguishing of fire

The Building Regulations and Codes prescribe the minimum fire safety requirements. Generally the national or the municipal fire legislation concerns for life safety, whereas insurance-orientated Codes are designed to minimize loss property.

**Means of escape**
The main objective of providing means of escape in buildings is to ensure safe evacuation of all occupants to a place of safety. The escape routes should remain safe for the duration for which they are needed, be clearly visible to the users and be located and sized to meet the needs of all occupants, taking into account the use of the building.

Smoke presents the highest hazard to escape. Control provisions therefore are needed almost in all buildings except perhaps in dwellings, to ensure that most parts of escape routes will remain clear of smoke as long as they are needed. There are different techniques for smoke control i.e. smoke control doors, pressurization, smoke expulsion systems and smoke extraction systems.

Most of the escape factors and sub-factors interact with each other. The most important from the design point of view is the effect of fire detection and the means of smoke control. Interactions also exist between the fire control and fire fighting provisions and the escape facilities.

Many current fire codes recognize the need for alternative escape routes in the cases of high occupancy levels and of multi-story buildings. This is especially the case when rescue is not possible from the outside due to the height of the building and its inaccessibility.

**Fire growth and fire containment**
The main objective of the provisions against fire growth is the reduction of the chance of fire incident in a building and in case of such an occurrence, the control of the rate of growth and spread to permit evacuation and to facilitate fire extinction. The rate of growth of a fire in an enclosure depends upon the following factors:

- Contents (ignitability, distribution, rate of heat release)
- Linings (thermal absorptivity)
- Compartment (size, shape, ventilation conditions)
- Interaction between contents, linings and room boundaries

The main objective of fire containment is to ensure that under fully developed fire the building will not collapse or become unstable and the fire will be contained within the boundaries. This assumes that a fire reaches a fully developed stage without being
attacked and controlled either by a human agency or by automatic means. It is known that most fires take enough time to reach a fully developed stage. This time is variable and unpredictable. An important function of fire containment is to limit fire damage and this is often the reason for its specification. The main purposes of fire containment could be summarized as below:

- To keep safe the escape routes
- To protect occupants in adjacent compartments
- To limit the amount of damage
- To prevent fire spread to neighbouring buildings
- To facilitate fire fighting

**Active fire protection**

The main task of active fire protection measures is to operate defensive and protective installations on the case of a fire, which provide safety for occupants by giving warning of a danger, activating extinguishing devices and providing facilities for fighting fires. The active fire protection measures differ from the passive measures in that they require the occurrence of a fire to operate the system, which has been provided as a safety precaution. The distinction between active and passive fire protection is not always very clear such as some measures are sometimes a combination of both, i.e. smoke control doors which remain open under normal circumstances but are automatically closed on receiving a signal from a detecting device. The doors remain part of the passive system but the detection and operating mechanism is an active measure.

For life safety the critical factors are the interval from ignition to the awareness of fire and from awareness to the time at which conditions become hazardous for occupants. In order to have the maximum time available for evacuation the interval time between ignition and awareness must be as short as possible. The main factors which affect the importance of awareness time as a critical issue are the fire origin and type and the occupant location and status.

Early fire detection has a significant effect on the objective of life safety and some effect on property protection provided that detection leads to other actions, which help rapid fire control. Early detection allows the occupants to leave the fire area whilst conditions are still safe, permits more effective use of the escape routes, provides more time for evacuation of disabled occupants and makes fire control easier. In some cases detection should initiate other actions, such as closing automatically doors, warning the fire brigade and the management of the building.

The provision of facilities for controlling and extinguishing fires can be sub-divided into three groups: a) first aid appliances, b) fixed installations c) equipment for the Fire Service. Into the first group we can include the portable extinguishers and the hose reels, in the second the automatic sprinklers, CO\textsubscript{2} and Halon systems (now the alternatives of Halon) and in the third the hydrants, safe bridgeheads, access and information.

It has been suggested and it seems to be the practice in many countries that where approved active measures are provided it should be possible to allow some relaxation on some passive measures. This approach is commonly defined as a “trade-off”. It is clear that it is not easy to establish a proper system for a balanced scheme for passive
and active fire protection. In order to strike a balance between passive and active fire protection measures and to provide designers with a flexible system in which various components can be adjusted to suit a particular set of conditions some clear equivalencies between them must be established.

**Advanced fire safety design**

In planning for fire protection of historic buildings the following main steps should be proceeded by the designers:

- Make a risk assessment
- Develop fire safety criteria
- Identify fire hazards
- Consider building’s arrangement
- Plan a fire protection strategy
- Specify passive fire protection
- Specify active fire protection
- Develop a fire safety management plan

It may be feasible to use traditional approaches for some historic buildings, where they can be categorized in one of modern occupancies (i.e. offices, museums etc.). However, for the majority of historic buildings, especially those erected many years ago, such an approach could cause not only serious technical and financial problems, but it might lead to undesired results about the historical and the architectural character of buildings, which are often unacceptable by the conservationists.

It would be necessary either to go through a clear and sophisticated process like that mentioned above, or to use a modern fire safety engineering methodology, which principles are described in a series of ISO Technical Reports 13387 (1999)

**INTERNATIONAL ACTIVITIES**

**Review**

The year 1975 was declared as the “year of protection of cultural heritage” by the European Council. Lord Duncan spoke about the demand of fire protection of the remained cultural heritage as European community first priority.

On behalf of German insurers group Kallenbach et. published a documentation of important losses of German historic buildings in peace-period since 1945. Kabat presented his experiences with fire safety concepts for historic buildings in the famous cathedral of the city of Worms in Germany. The German Fire Protection Association (VFDB) used their annual meeting (1987) to bring the attention of the public to the problems of fire protection in historic buildings. [6]

The international Symposium “Protection of cultural heritage against the threat of fire” hosted in Karlsruhe (1990) co-organized by VFDB (prof. W. Becker) and CIB-WG 014 (Dr. P. Thomas-prof. K. Papaioannou). As consequence of that Symposium new guidelines of CIB had been drafted by K. Papaioannou (Aristotle University-Hellas) and H.L. Malhotra (Fire Research Station, UK) et. al.

“Conservation of Cultural Heritage” was stated goal of the ISO-TC92-SC4 (Fire Safety Engineering) ISO/DTR 13387-1 (1998). Since then, a lot of activities have taken place but it seems that is difficult to create some generally accepted documentation

**RESEARCH PROJECTS**
A summary of two important European research activities is given below.

1. A European Concerted Research Action designated as COST

Summary
The intention of the Action is to address the physical and significant cultural loss of Europe’s built heritage to the damaging effects of fire. It will be achieved in a multi-disciplinary, multi-national manner through the collaboration and integration of a variety of related projects. It will also build upon current research initiatives and recently published material resulting from a number of relevant international conferences. The outcomes will be the promotion of data, methodologies, and management systems. This will assist a wide range of end-users balance fire engineering needs with conservation requirements in the future preservation of the European patrimony.

Why a COST Action on this topic
In addition to associated levels of life loss, the number, authenticity and quality of European historic buildings is being steadily eroded through the effects of fire. In 1983 this was recognised by the Council of Europe Committee of Ministers, who recommended ‘That the governments of the member states adopt all legislative, administrative, financial, educational and other appropriate measures’ to protect the built heritage from fire and other natural disasters. Therefore there is a need to find a balance between technological and management solutions to counter this disastrous effect of fire.

The real scale of loss of historic buildings to fire is unknown but superficial data suggests that the annual and aggregated effect is considerable, perhaps as high as one important historic building each day.

There is a general lack of statistical information, and a common lack of understanding and appreciation of what measures are available and required, to counter the effects of fire. Good guidance is urgently called for on how to sensitively retrofit modern day equipment into historic fabric. There is also a need to develop related management expertise in the dealing with this problem in historic premises.

Status of the research in the field
To assess the specific risks to a historic building requires the need to define possible, or expected, damage due to a particular hazard or phenomenon. The term “historic building” should be taken to be synonymous with the entire architectural heritage - comprising monuments, groups of buildings and sites, as well as movable objects having particular historical or aesthetic association with the protected building. There are a considerable number of historic buildings requiring protection. It is important to recognise that these historic buildings are a major contributor to the ‘sense of place’ and recent information indicates that they are of great importance to both inhabitants and tourists. In some countries, the most important historic buildings are included on statutory lists. However, the criteria for selecting buildings for inclusion change from country to country. These listed buildings form only a small percentage of the total number of buildings which can be considered as part of the built heritage. As an indication, there are almost 36,000 listed buildings in Austria, 110,000 in Bavaria and 45,000 in Scotland, but detailed figures for all of Europe are lacking.

To be effective in the resolution of this problem, the need is to develop a high level of international co-ordination and strengthen the levels of trans-national multi-
disciplinary co-operation. The need is to exchange and enhance experiences to increase awareness and understanding, and to focus future action. Networking partnerships have been identified, their specialist input recognized and roles they perform classified. The associated skill and knowledge needs to be pooled, assessed and best practice developed.

During the 1990's several international conferences considered the topic of fire loss to the built heritage. But these did not provide the mechanism for encouraging and co-ordinating research projects. However, published proceedings offered an established understanding of the issues, although many of them remain un-resolved in practical terms.

2. **Fire Risk Evaluation to European Cultural Heritage** (FIRE-TECH)

*Quantification of priorities and optimisation of fire protection strategies*

**Scientific objectives and approach:** The first scientific objective was the development of an evaluation tool taking into account all the parameters expected to influence decisions when prioritising fire protection projects in cultural heritage. This objective includes the elaboration of quantitative methods or the adaptation of existing ones for the evaluation of the different parameters/criteria intervening in the decision process. These parameters are the fire-risk, the efficiency of the measures, their cost.

In parallel with scientific objective one, the second objective is to give an overview and examine the relative benefits and drawbacks of the various components of fire safety techniques. This means a comparison between the different possible strategies of protection, identification of the weaknesses of the existing techniques and the proposal of alternative solutions. Usual fire protection techniques are often not applicable and/or not acceptable for the protection of cultural heritage. There is important lack of specific information on fire safety technology for cultural heritage.

**Expected impacts:** Under this project an evaluation tool has been developed to assist authorities in prioritising fire protection projects and selecting projects on the basis of objective criteria. These take into account all the selected criteria/aspects in order to optimise the use of the available financial resources by the selection of those projects providing the highest gain for the investment made. Additionally a guide has been developed describing the state of the art of fire safety technologies and the use of fire safety engineering approaches to protect cultural heritage. The information has been made available to all interested parties by means of a symposium organised at the end of the project and the publication of a guidance document under book format.

**Innovative aspects of the project**

The problems of fire protection of a cultural heritage have been approached from the viewpoint of ‘fire safety engineering’. Important recent fire losses of cultural heritage have been systematically listed and analysed. Conclusions have been drawn on the origin of the fires, their development. A fire risk analysis method focussing cultural heritage will be elaborated.

Existing fire protection techniques have been reviewed in respect to their applicability, reliability, efficiency and cost. The fire behaviour of ancient building products has been examined. A quantitative optimisation method has been
elaborated to assist authorities when selecting projects to spend the financial means in the most efficient way. The optimisation method will combine aspects such as fire risk, efficiency versus cost of protective techniques.

Fire safety engineering approaches have been analysed and evaluated for their potential merits when applied in cultural heritage.

Project Membership

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<td>2 Warrington Fire Research (WFR)</td>
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CONCLUSIONS

REFERENCES

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