A CRITICAL REVIEW ON FIRE RESISTANCE STRUCTURES

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ABSTRACT

Basic concepts of risk-informed decision making for mitigating fire risk, and a general framework for assessing fire risk to building construction and for developing structural design requirements for fire conditions are described. Current best knowledge in thermal and mechanical properties and behaviors of normal strength concrete, high strength concrete, structural steel, and several major groups of common fire protection materials at elevated temperatures, which are necessary for performance-based engineering calculation, are presented. Modern fire-resistant design methodologies for concrete and steel structures are discussed, including methods based on standard fire tests as well as performance-based engineering analysis methods that involve heat transfer and structural analysis at elevated temperatures.

Keywords: Building codes; concrete structures; design fire scenarios; fire-resistant design; fire risk mitigation.

INTRODUCTION

One of the main reasons why Portland cement concrete is so widely used in building construction is that it can help satisfy the cardinal need for public safety in the face of the hazards of fire better than most alternative materials. Concrete is non-combustible and a reasonable insulator against the transmission of heat. In many applications, the main role of concrete in a fire is to protect any embedded steel for as long as possible against a rise in temperature to the point where its physical properties are reduced significantly, causing excessive structural deflections that might lead ultimately to collapse.

A new approach to high rise safety began emerging that required buildings to be constructed of columns, floors, walls and other elements that were fire resistive, defined as the ability of an element to withstand the effects of fire for a specified period of time without loss of its fire separating or load bearing function. Various temperature-time curves are used today, depending upon the country and application. Figure 1.1 compares the ISO 834 test, the hydrocarbon fire

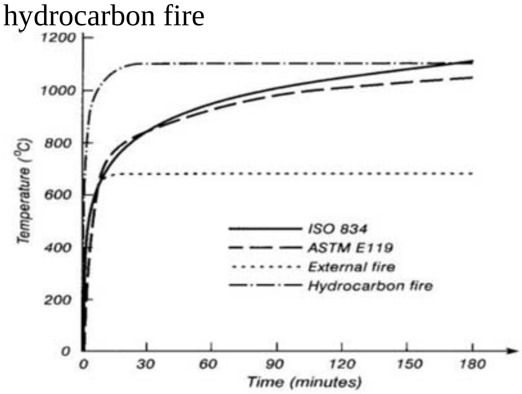

Figure 1:Temperaturevs. Time

A. *CONCRETE PROVIDES COMPREHENSIVE FIRE PROTECTION:*

Reducing deaths in fire and the impact of fire damage requires a comprehensive approach to fire safety. The aim is to ensure that buildings and structures are capable of protecting both people and property against the hazards of fires. But private owners, insurance companies and national authorities may also have interests in fire safety for other reasons, such as **economic survival, data storage, environmental protection and upkeep of critical infrastructure**.

Structural fire protection measures must fulfil three aims:

i. **Personal protection** to preserve life and health;
ii. **Protection of property** to preserve goods and other belongings both in residential or commercial units that have caught fire, and in neighbouring properties. To this must be added substantial preservation of the building structures;
iii. **Environmental protection** to minimise the adverse effects on the environment through smoke and toxic gases as well as from contaminated water used for extinguishing fire.

Using concrete in buildings and structures offers exceptional levels of protection and safety in fire:

i. Concrete does not burn, and does not add to the fire load.
ii. Concrete has high resistance to fire, and stops fire spreading.
iii. Concrete does not drip molten particles, which can spread the fire
iv. Concrete is easy to repair after a fire, and so helps businesses recover sooner.
v. Concrete does not produce any smoke or toxic gases, so helps reduce the risk to occupants.

B. *PROTECTING PEOPLE:*

Very often fire threatens human life. This fact drives improvements in fire safety and compels us to design buildings that are capable of protecting people and their property against the hazards of fires. Concrete buildings and structures give personal protection against fire to preserve both life and health. Concrete behaves in fire, and how its material properties function effectively in terms of fire resistance .Life protection relies on concrete's inherent robustness, its non-combustibility and heat shielding properties to ensure that buildings remain stable during fire. This enables people to survive and escape, it allows fire-fighters to work safely and, what's more, it reduces the environmental impact caused by combustion products – this section explains how.

Risks of using combustible construction materials

1. An increase in fire load.
2. An increase in smoke and pyrolysis products.
3. Higher amounts of carbon monoxide.
4. Fire ignition of structural elements.
5.Fire ignition inside construction cavities.
6. Danger of smouldering combustion and imperceptible glowing
7. Increasing occurrence of flashover

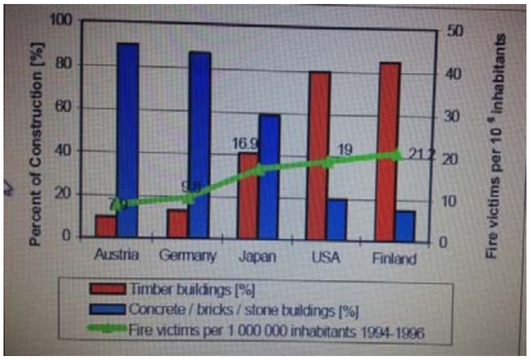

Figure 1.2: Fire deaths compared with construction type in five major countries

C. *Cementitious spray-fire proofing:*

Fireproofing's rendering something (structures, materials, etc.) proof against fire, or incombustible; or material for use in making anything fire-proof. It is a passive fire protection measure.

Figure 1.3: Construction worker applying spray resistive material

How can the surface appearance of the spray-fireproofing be improved?

i. **Hand troweling** may be applied to some spray applied fireproofing products to improve the surface appearance of the products.

ii. Surface decorative paint may be used as an Overspray on spray-applied fireproofing products for sealing, surface colouring or to increase light reflection.

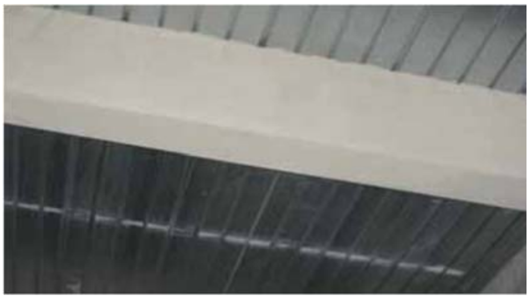

FIGURE 1.4: Steel member with Hand troweling cementious spray fire proofing

Alternative fireproofing methods:

Among the conventional materials, purpose-designed spray fireproofing plasters have become abundantly available the world over. The inorganic methods include:

i. Gypsum plasters
ii. Cementitious plasters
iii. Fibrous plasters

Gypsum plasters have been lightened by using chemical additives to create bubbles that displace solids, thus reducing the bulk density. Also, lightweight polystyrene beads have been mixed into the plasters at the factory in an effort to reduce the density, which generally results in a more effective insulation at a lower cost. Fibrous plasters, containing either mineral wool, or ceramic fibres tend to simply entrain more air, thus displacing the heavy fibres.

FIGURE 1.5: Spray gypsum based plaster fireproofing being installed.

D. *List of fire-retardant materials:*

Fire retardant materials should not be confused with fire resistant materials. Whilst a fire resistant material is one that is designed to resist burning and withstand heat, fire retardant materials are designed to burn slowly.

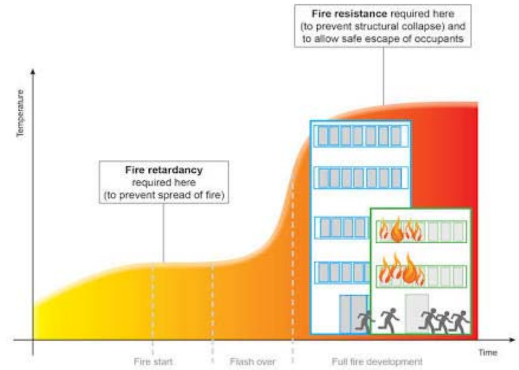

Figure 1.6: Showing the difference.

Fire-retardant materials used in buildings:

i. Rock wool
ii. Gypsum boards
iii. Asbestos cement
iv. Perlite boards
v. Proplex Sheets
vi. Calcium silicate boards
vii. Treated lumber plywood

Concrete prevents fire spread following earthquakes

The seismic design considerations that apply in some countries require designers to pay attention to thespecific problem of fires following earthquakes. This has been given due consideration in countries such as New Zealand, where concrete structures have been identified as having a low level of vulnerability to the spread of fire following earthquakes.

E. *FIRE RESISTANT BUILDINGS REQUIREMENTS:*

A building may be made more fire resistant by:

1. Using suitable materials.
2. Taking precautions in building construction
3. By providing fire alarm systems and fire extinguishers.

Using Suitable Materials:

The fire resisting material is having the following characters:

(a) It should not disintegrate under the effect of heat
(b) It should not expand under heat so as to introduce unnecessary stresses in the building
(c) The material should not catch fire easily
(d) It should not lose its strength when subjected to fire.

Fire resisting characteristics of some of the commonly used building materials are:

Stone: It is a bad conductor of heat. Sand stones with fire grains can resist fire moderately.

Granitedisintegrate under fire.

Lime stone: crumbles easily. Most of the stones disintegrate cooling period after heated by fire. **Brick:** Bricks can resist heat up to 1200°C. At the time of construction, if good quality mortar is used, fire resistance is extremely good. **Timber:** Any structure made of timbers is rapidly destroyed in fire. Timber enhances the intensity of fire. Use of heavy sections of timber in buildings is not desirable. To make timber more fire resistant the surface of timber is coated with chemicals such as ammonium phosphate and sulphate, boric acid and borax. Sometimes fire resistant paint is applied to timber used in the building.
Concrete: Concrete has got very good fire resistance. The actual behaviour of concrete in case of fire depends upon the quality of cement and aggregates used. In case of reinforced concrete and prestressed concrete, it also depends upon the position of steel. Larger the concrete cover, better is the fire resistance of the member.

There is no loss in strength in concrete when it is heated up to 250°C. The reduction in strength starts if the temperature goes beyond 250°C. Normally reinforced concrete structures can resist fire for about one hour at a temperature of 1000°C. Hence cement concrete is ideally used fire resistant material. **Steel:** It is a good conductor of heat. Steel bars lose tensile strength. Steel yields at 600°C. They melt at 1400°C. Steel columns become unsafe during fire. Steel reinforcement weaken the reinforced concrete structures. Hence steel columns are usually protected with brick works or by encasing in concrete. Steel grills and beams are applied with fire resistant paints. **Glass:** It is a poor conductor of heat. It expands little during heating. After heating when it cools, cracks are formed in glass. **Aluminium:** It is good conductor of heat. It has got higher resistance to fire. **Asbestos Cement:** It is non-combustible material. It possesses high fire resistance.

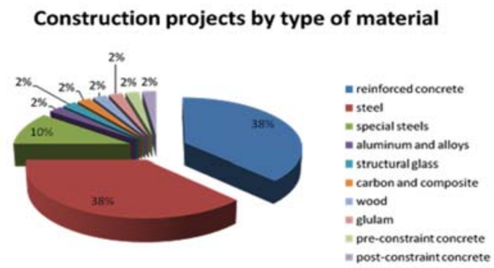

Figure1.7:Percentage of materials used.

F. *FIRE RESISTANCE DESIGN CONSIDERATIONS.*

Fire safety is provided in a building by a combination of active fire suppression and passive fire protection. Active fire suppression includes fire fighting and automatic devices, such as sprinklers, to control the spread of fire. Passive fire protection includes measures, such as fire barriers, that control the spread of fire or insulations, such as concrete cover and spray-applied fire protection that delay the effects of fire on the structurecollapse in fire.

The following approaches can enhance fire resistance in buildings:

i. Control fuel quantity and locations.
ii. Control fire spread.
iii. Control ventilation characteristics.
iv. Protect construction materials.

Loads for Structural Fire Design:-

The most likely loads at the time of a fire are much lower than the maximum design loads specified for normal temperature conditions. Most codes refer to an “arbitrary point-in-time load” to be used for the fire design condition. As an example, the ASCE document (ASCE 2005) gives the design load combination for fire Uf as

$$U_f = 1.2D_n + 0.5\,L_n$$

Where, Dn and Ln are the design levels of dead and live load respectively

Design Equation:-The fundamental step in designing structures for fire safety is ,

Fire resistance ≥Fire severity

Where:

i. *Fire resistance* = A measure of the ability of the structure to resist collapse, fire spread.

ii. *Fire severity* = A measure of the destructive impact of a fire

CONCLUSION

Concrete’s excellent fire resistance has been proven by many tests performed for over 60 years. The American Concrete Institute and various building codes have developed prescriptive and analytical methods based on the fire tests on concrete components of structures. These methods provide architects and engineer a relatively easy way to select member proportions and reinforcement requirements for all but the very unusual structures. For the very unusual structures, alternate methods are available to adequately model or to test the complex behaviour of reinforced concrete components subject to fire. Despite potential deficiencies in performance at elevated temperatures arising from dehydration and thermal incompatibilities, concrete has a long-standing and justified reputation as a fire-resistant material, notwithstanding a long-recognized need for better means of testing and specifying endurance.

Development of temperature regime-structural behaviour models and greater understanding of thermal and mechanical properties are leading to significant improvements in specification and design against the extremes of fire and for moderately high temperature applications such as nuclear reactors. While striking advances have been made, full physical-chemical, thermodynamic explanations that tie together all the aspects of the very complex viscos-elastic, moisture-dependent behaviour pattern of concrete at elevated temperatures are still awaited.

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